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STATISTICS OF POWER AND MACHINERY EMPLOYED IN MANUFACTURES.

PROF. W. P. TROWBRIDGE,
CHIEF SPECIAL AGENT.

REPORTS

ON THE

WATER-POWER OF THE UNITED STATES.

PART II.

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PART II.

WATER-POWER OF THE UNITED STATES.

TABLE OF CONTENTS OF PART II.

Folio at bottom of page.

THE WATER-POWER OF THE NORTHWEST.

By JAMES L. GREENLEAF, C. E., etc 7–118

THE WATER-POWER OF THE MISSISSIPPI RIVER AND SOME OF ITS TRIBUTARIES.

By JAMES L. GREENLEAF, C. E., etc 119–276

THE WATER-POWER OF THE REGION TRIBUTARY TO THE MISSISSIPPI RIVER ON THE WEST, BELOW DUBUQUE.

By DWIGHT PORTER, Ph. B., etc 277–428

THE WATER-POWER OF THE OHIO RIVER BASIN AND OF THE OHIO STATE CANALS.

By DWIGHT PORTER, Ph. B., etc 429–504

THE WATER-SUPPLY OF CERTAIN CITIES AND TOWNS OF THE UNITED STATES.

By WALTER G. ELLIOT, C. E., Ph. D., *Special Agent* 505–788

REPORT

ON THE

WATER-POWER OF THE NORTHWEST.

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TABLE OF CONTENTS.

Page.

LETTER TRANSMITTING THE REPORT xiii

GENERAL REMARKS UPON THE WATER-POWER OF THE NORTHWESTERN STATES 1

SYSTEM OF DRAINAGE AND AREAS OF DRAINAGE BASINS 1

Limits of the region—System of drainage—Table of drainage areas—Principal line of watershed—Elevations of watershed line—Ancient hydrography 1,2

TOPOGRAPHY AND CHARACTER OF THE COUNTRY 3

Lake Superior region—Country south of lake Superior—Distribution of the timber—Prairie region—Character of the soil 3,4

CHARACTER AND DISTRIBUTION OF THE WATER-POWERS 4

Streams of the prairie region—Streams of the rugged region—Value of the water-powers—Distribution of the water-powers—Upper Mississippi basin—Western drainage area of Lake Michigan—Basin of the Red River of the North—Streams of the western portion of Lake Superior 4,5

GEOLOGY OF THE REGION IN ITS BEARING ON THE WATER-POWERS 6

Cause of the form of the drainage system—Glacial Age—Origin of the Minnesota lakes—Relative influence of the metamorphic and sedimentary rocks upon the streams 6,7

FLOW OF THE STREAMS AND CONDITIONS AFFECTING IT 7

Impossibility of accurate calculations—Amount of aqueous precipitation—Climatic effects—Times of freshet and drought—Effects of mountainous and of level countries—Influence of sand and gravel beds—Influence of fissured rock—Action of woodland—Effects of prairie cultivation—Lakes of the northwest—Table of distribution of the lakes—Comparison of lakeless with reservoir streams—Table of flow per square mile of drainage area—Influence of swamps—Classification of the lakes—First class—Second class—Lakes without inlets—Third class—Gradual filling of the lakes—Summary 7-13

WESTERN DRAINAGE AREA OF LAKE MICHIGAN 13

GENERAL REMARKS 13

The watershed line—Twofold division of the drainage area—Table of areas of drainage basins—Basin of the Lower Fox—Menominee river basin—Table of aqueous precipitation and temperatures—Distribution of the precipitation. 13-15

LOWER FOX RIVER 15

HISTORY OF THE REGION .....

RESOURCES OF THE REGION 16

Natural productions—Railroads—Waterways 16

PHYSICAL DISCUSSION OF THE LOWER FOX 17

System of drainage—Overflow from the Wisconsin river—Peculiarity of the Fox river valley—Geological history—Ancient valley of the Wolf river—Green bay and lake Winnebago valley—Glacial action—Expansion of lake Michigan—Origin of lake Winnebago—Summary of the remarks on the geology 17-19

LEGAL CONDITION OF THE WATER-POWER 19

Legal history of the water-powers—Classification of the powers—Rates of lease—Green Bay and Mississippi Canal Company 19,20

CHARACTERISTIC FEATURES OF THE RIVER AS A WATER-POWER STREAM 20

Past and present—Government dams—Table of locations of the government dams—Flow of the river and the water-power—Table of amounts of powers—Uniformity of flow—Lake Winnebago—Storage capacity—Freshets from the Wolf and Upper Fox rivers—Springs in lake Winnebago—Artificial reservoirs—Fluctuations due to the mills—Features favorable to water-power 20-23

NEENAH AND MENASHA—Fall and power—Menasha—Neenah 24

Water-power diagrams for the Lower Fox river 25,26

THE RIVER FROM NEENAH AND MENASHA DOWN TO APPLETON 27

APPLETON 27

Freighting facilities of Appleton—Navigation channel—Upper level at Appleton—Fall and power—North shore race—Long pier—Ship canal—Unused power—Middle level at Appleton—History of the middle level—Fall and power—North shore race—The basin—West's canal—Lower level at Appleton—Fall and power—West shore race—Hyde & Harriman canal 27-34

THE RIVER FROM THE LOWER LEVEL AT APPLETON DOWN TO CEDARS 35

Page.

WESTERN DRAINAGE AREA OF LAKE MICHIGAN—Continued.

CEDARS 36
Fall and power 36
LITTLE CHUTE 36
Fall and power—Improvements possible—Means of freightage 36-38
GRAND KAUKAUNA 38
Fall and power—Ship canal—Kaukauna Water-power company—Edwards & Meade power—Proposed improvements. 39, 40
THE RIVER FROM GRAND KAUKAUNA DOWN TO RAPIDE CROCHE 41
RAPIDE CROCHE 41
Fall and power .....
THE RIVER FROM RAPIDE CROCHE DOWN TO LITTLE KAUKAUNA 42
LITTLE KAUKAUNA 42
Fall and power 42
DEPÈRE 44
Fall and power .....
DAMS AND OTHER CONSTRUCTIONS ON THE RIVER 44
Table of dams—Stone pier at Appleton—Dam at upper level, Appleton—Dams at lower level, Appleton—Dams at Cedars, Little Chute, and Rapide Croche—Dam at Grand Kaukauna—Dam at Depère—Dam at Little Kaukauna—Dam at Menasha—Dam at middle level at Appleton—Method of building—Miscellaneous constructions—Cheap form of coffer dam—Wooden bulkheads 44-52
TRIBUTARIES OF THE LOWER FOX 52
WOLF RIVER 52
Surrounding country—The river below Shawano—The river above Shawano—Flow of the river—Mills on the Wolf river—Tributaries of the Wolf river 52, 53
UPPER FOX RIVER 54
Ancient course of the Upper Fox—Table of data for the upper Fox river—Cut-offs—Mills on the upper Fox—Discharge from the Wisconsin river—Tributaries of the Upper Fox river 54, 55
RIVERS OF THE REGION NORTH OF THE LOWER FOX RIVER SYSTEM 55
Description of the lumber business—Iron mining—Field for manufacturing 55, 56
MENOMINEE RIVER 57
Dimensons of the drainage basin—Geological character of the Menominee basin—Influence of the rock strata—Main topographical features—Volume of the Menominee and its power—Estimate of the flow from the rainfall—Table of data for the Menominee—The rapids of the Menominee—Table of data of the rapids—Utilized power upon the Menominee 57-63
TRIBUTARIES OF THE MENOMINEE 63
Table of data of the tributaries—Bois Brulé—Mequacumecum river—Michigamme river—Pine river—Sturgeon river. 63, 64
DAMS UPON THE MENOMINEE 65
Upper dam—Middle dam—Lower dam—Method of building 65-67
MILWAUKEE, SHEBOYGAN, AND MANITOWOC RIVERS 67
Nature of the drainage area—Data for the rivers—Estimated power—Peculiarity of the Milwaukee river 67, 68

SAINT LOUIS RIVER, AND OTHER STREAMS OF THE WESTERN DRAINAGE AREA OF LAKE SUPERIOR 68
GENERAL REMARKS 68
SAINT LOUIS RIVER 70
Importance of its geographical position—Special value of water-power—Transportation facilities—Proposed canal—Lumber interests—Character of the country—Upper and lower sections of the river—Rock of the lower section—Tributaries—Volume of flow of the Saint Louis river—Estimation of the flow from the rainfall—Table of data on the Saint Louis river—Above the Big White Face—Big White Face to Floodwood river—Floodwood to Cloquet river—Grand rapids—Knife Falls to Thomson 70-74
RAPIDS OF THE SAINT LOUIS 74
Fall and power of the Rapids of the Saint Louis—Water-power company—Power owned by the company—Proposed improvement 74, 75
RIVERS OF THE SOUTH SHORE OF LAKE SUPERIOR IN WISCONSIN 76
Topography—Rock and soil—Flow of the streams—Table of data of the streams—Bad river—Montreal river—Bois Brulé River—Nemadji river 76-78

THE RED RIVER OF THE NORTH, AND ITS DRAINAGE BASIN 79
GENERAL REMARKS 79
Course of the river—Production of the region—Transportation facilities 79
PHYSICAL GEOLOGY OF THE DRAINAGE BASIN 79
Change in drainage—Glacial action—Indications of the change in drainage—Cause of the change in drainage—General Warren's theory—Professor Winchell's theory—Geological structure 79, 81
GENERAL DESCRIPTION OF THE BASIN 82
Limits of the basin—Cross section of the basin—Elevations—Twofold geographical division of the basin—The lakes—Timber 82-84
DESCRIPTION OF THE RIVER FROM THE NORTH TO WHERE IT ENTERS THE HILL COUNTRY EAST OF BRECKINRIDGE 84
System of improvement—Width of the river—Slope of the river—Bed of the river—Floods and their causes—Goose River Rapids—Water-power of Goose River Rapids—Bois de Sioux river 84-87
DESCRIPTION OF THE RIVER IN THE HILL COUNTRY, OR WATER-POWER REGION 87
Distribution of the fall—Uniformity of flow—Flow and power—Dayton to Fergus falls 87

Page.

THE RED RIVER OF THE NORTH AND ITS DRAINAGE BASIN—Continued.

FERGUS FALLS 87
Table of power at Fergus Falls—Description of the power—Location of the town 87
THE RIVER ABOVE FERGUS FALLS 88
Location of the power 88
TRIBUTARIES OF THE RED RIVER OF THE NORTH 89
OTTER TAIL RIVER 89
Utilized power 89
PELICAN RIVER 89
Improved powers 89
RED LAKE RIVER 89
Red lake—Fall—Flow and power—Available powers—Power at Crookston—Plan of improvement at Crookston—Unimproved power above Crookston 89-91
CLEARWATER RIVER 91
SHEYENNE RIVER 91
Power—Utilized power—Construction of dam 92
DISCUSSION OF THE TABLES OF RAINFALL, DRAINAGE AREAS, FLOW, ETC 92
Explanation of the difference between the eastern and western tributaries—Comparison of the upper portion of the river with the Bois de Sioux—Comparison of different sections of the river—Table of aqueous precipitation and temperatures—Table of data for the Red River of the North—Table of data for the tributaries 93

LIST OF ILLUSTRATIONS.

Page.

Geological section on an east-and-west line through the southern end of Lake Winnebago, Wisconsin 18
Water-power diagrams for the Lower Fox river 23
Lower Fox river at Menasha, Wisconsin 25
Lower Fox river at Neenah, Wisconsin 26
View of the Lower Fox river at Appleton, Wisconsin 28
Appleton, Wisconsin: View of West's canal from the lower end 32
Appleton, Wisconsin: Lower dam, from the ship-canal bank 33
Appleton, Wisconsin: The Hyde & Harriman canal, lower level, looking up-stream 34
Lower Fox river at Cedars, Wisconsin 35
Lower Fox river at Little Chute, Wisconsin 37
Lower Fox river at Rapid Croche, Wisconsin 41
Lower Fox river at Little Kaukauna, Wisconsin 42
Lower Fox river at Depere, Wisconsin 43
Appleton, Wisconsin: View of upper dam in process of construction 46
Dam at upper level, Appleton, Wisconsin 46
Plan of crib-dam at Cedars, Little Chute, and Rapid Croche, Wisconsin 47
Crib-dam at Depere, Wisconsin 48
Pile-dam at Little Kaukauna, Wisconsin 49
Abutment of dam at Little Kaukauna, Wisconsin 50
Middle dam at Appleton, Wisconsin, from Grand Chute island 50
Dam at middle level, Appleton, Wisconsin 51
Bulkheads of the Hyde & Harriman canal, lower level, Appleton, Wisconsin 52
Big Quinnesee Falls, Menominee river 60
Lower dam on the Menominee river at its mouth 65
Upper dam at the mouth of the Menominee river 66
Lower dam at the mouth of the Menominee river 66
Drainage basin of the Saint Louis river 69
Rapids of the Saint Louis river 70
Rapids of the Saint Louis 74
Southern drainage area of Lake Superior in Wisconsin 77
Sections across the valley of the Red river of the North at Moorhead 83
The source of the Red river of the North in the lakes of Minnesota 86

LETTER OF TRANSMITTAL.

NEW YORK, *October* 1, 1881.

Professor W. P. TROWBRIDGE,
Special Agent in charge of the Statistics of Power and Machinery for the Tenth Census.

DEAR SIR: In accordance with the directions received on May 28, 1881, I respectfully submit the accompanying report on the water-power of the northwest, as a report of progress.

As will be seen on examination of the papers, the region discussed in detail includes only those drainage areas surrounding the basin of the extreme upper portion of the Mississippi river.

First, there is a general discussion of the entire region, including the upper Mississippi basin; then follow the sections devoted to the different drainage areas, in the following order:

Western drainage area of lake Michigan, Saint Louis river, and streams of the south shore of lake Superior. Drainage basin of the Red River of the North.

Very little information was obtained about the rivers of the extreme northern portion of Minnesota and the upper peninsula of Michigan; those regions are in a wild, undeveloped condition, and no personal examination was made, although a considerable amount of water-power exists there.

Next I consider the extensive water-power of the Mississippi itself.

In writing this report the aim has been to keep in view all the features of the country of significance in their relations to the subject of water-power.

Thus, in describing a drainage basin, the general plan which it has been endeavored to carry out is to give the prominent characteristics of the region as regards topography and the drainage system, to state the geological history in its relations to the hydrography, to describe the industrial occupations of the inhabitants, and the manufacturing interests, with the facilities for traffic, and to consider the size and flow of the streams, the amount of fall and water-power, with its distribution, giving a detailed description of the important powers.

The territory visited during the winter and spring of 1880–'81 included the region above mentioned, all the eastern portion of the Mississippi basin down to the Gulf, with the exception of the Ohio river, a number of the rivers flowing into the gulf of Mexico, and all the western portion of the Mississippi basin down to the central part of Iowa.

In order to complete this district in proper season, it was impossible to obtain full and detailed information of all the different powers by personal examination, and long excursions away from the railroads were out of the question; hence the method was pursued of visiting the important water-powers, and there obtaining all the information available relative to the streams above and below.

Areas of drainage basins were calculated by means of a planimeter, either from the maps of the United States land office or from large and detailed state maps. The lengths of streams were also usually measured on these maps, and where that is the case the figures can only be considered approximations. It cannot be claimed that even the maps issued by the United States government for this region are correct in all their details, but errors from this cause would not occur to any great extent in calculating drainage areas.

Estimates of the flow of the streams, the elevations, etc., were obtained, where possible, from the records of the United States engineers, to whose invariable courtesy this report is much indebted. In some cases no data are available except rough estimates as to the capacity of the powers. It was impracticable to make accurate personal measurements, and nothing of that kind was attempted. Where no reliable figures for the flow are available, an approximation has been made by comparing with neighboring streams and estimating it from the rainfall. In all such cases the calculations are made for an ordinary low-water stage, as that is the volume of the streams used in practice in estimating powers. Wherever actual gaugings are available they have been used to the exclusion of all estimates

from the rainfall, as they are generally more to be relied upon for practical work. Particular attention has been paid to geology in its bearings upon the water-courses, as the water-powers owe their characteristics to so great an extent to the nature of the surface over which the streams flow.

With the hope that this report may receive your approbation,

I have the honor to be, most respectfully, yours,

JAMES L. GREENLEAF,
Special Agent of the Tenth United States Census.

NOTE.—The reports on the Mississippi and its tributaries and the rivers of the Gulf of Mexico which I visited, the drainage of lake Erie in the United States, and the water-power of Niagara Falls, will be found following in order the report on the Red River of the North. The succession in which the divisions are taken is, to some extent, the result of circumstances attending the requirements of the press; but it will be noticed that the regions around the Upper Mississippi basin are first discussed, then the Mississippi basin, passing south, then the Gulf drainage, and, finally, the streams of Lake Erie and the Niagara river. The remarks in the letter transmitting the earlier reports will apply equally to these later ones.

GENERAL REMARKS UPON THE WATER-POWER OF THE NORTHWESTERN STATES.

SYSTEM OF DRAINAGE AND AREAS OF DRAINAGE BASINS.

The territory under discussion includes the entire state of Wisconsin, the upper peninsula of Michigan, the state of Minnesota, with the exception of the southwestern corner, and the northeastern portion of Dakota. The eastern and most of the northern boundary of this region is a continuous water-line. On the east lakes Michigan and Superior form the boundary, and on the north lake Superior and the system of lakes and water-channels separate Minnesota from the British possessions. The approximate length of this water-line is 1,200 miles. On the west the boundary is the eastern water-shed line of the Missouri river.

A peculiar interest is connected with this section from a geographical point of view, as from it are gathered the waters which feed the frigid, the tropical, and the temperate seas.

The extreme source of the Red River of the North, which flows into Hudson bay; of the Mississippi, which pours its mighty flood into the Gulf of Mexico; and of the Saint Louis river, properly the head of the great lakes and the Saint Lawrence, are all situated on a straight line, 170 miles long, passing a little south of east through the northern part of the state of Minnesota. The Upper Mississippi, passing through the center of the region, is the great channel into which half its area drains southward.

Encircling the drainage basin of the Upper Mississippi is a belt of country, varying on the east and north from 2 or 3 miles to 100 miles in width, whose drainage is either eastward through the great lakes or northward by means of the Red River of the North. This naturally suggests a division of the water-power into that of the great lakes, that of the basin of the Red River of the North, and that of the basin of the Upper Mississippi.

DRAINAGE AREAS.

		Square miles.
Mississippi river in Dakota, Minnesota, and Wisconsin		82,130
Red River of the North in the United States		39,577
Lake Michigan in Wisconsin and Illinois	14,917	
Lake Michigan in upper peninsula of Michigan	7,834	
		22,751
North shore of lake Superior in Minnesota, including the Saint Louis river basin of 3,225 square miles		*a* 15,965
South shore of lake Superior in Minnesota	236	
South shore of lake Superior in Wisconsin	3,106	
South shore of lake Superior in upper peninsula of Michigan	7,834	
		11,176
Total area of entire region		171,599

PRINCIPAL LINE OF WATER-SHED.

The water-shed line which defines the basin of the Mississippi from the surrounding belt has a total length from the southern end of lake Michigan to where it strikes the southern boundary of Minnesota of 1,350 miles, thus distributed: Illinois, 70 miles; Wisconsin, 555 miles; Minnesota, 590 miles; Dakota, 135 miles. In Illinois this line is only 4 or 5 miles from the lake shore, receding but little to lake Winnebago, in Wisconsin; thence northward it is about 100 miles from lake Michigan, and then 30 miles from lake Superior. In Minnesota it takes a bend of about 75 miles to the north, and then turns southwest, entering Dakota at about the center of its eastern boundary; but it soon re-enters Minnesota, and crosses the southwestern corner of the state into Iowa.

a An indeterminate portion of this is tributary to lake Winnipeg, as mentioned beyond.

ELEVATIONS OF WATER-SHED LINE.

At the foot of lake Michigan this line of water-shed is elevated only a few feet above the lake, which is 589 feet above the sea. It rapidly rises in Wisconsin to 400 feet above the lake (989 feet above sea-level), then sinks to 230 feet above the lake at Portage city, Wisconsin (819 feet above sea-level), and then rises to 950 feet above lake Michigan (1,539 feet above the sea) at the boundary between Wisconsin and the upper peninsula of Michigan. Here the water-shed turns west, with an average elevation above lake Superior of 1,000 feet (1,609 feet above sea-level), sinking in the western part of Wisconsin to 600 feet above lake Superior (1,209 feet above the sea).

At the western end of lake Superior the water-shed line sinks very low, so that an engineer recently proposed a scheme for supplying the cities of Saint Paul and Minneapolis, in Minnesota, with water from lake Superior, the aqueduct crossing the line of water-shed by means of a siphon. The cause of this sinking is its crossing the western end of the synclinal trough occupied by lake Superior.

In Minnesota the water-shed line, in passing north, rapidly rises to about 800 feet above lake Superior (1,400 feet above sea-level), and about the headwaters of the Mississippi, in the northern portion of that state, it is at least 1,600 feet above the sea. It falls in passing south, and where it enters Dakota it is only 995 feet above sea-level. In Dakota it rises again, in one locality to at least 1,500 feet, and Spirit lake, near where the divide passes from Minnesota into Iowa, is 1,694 feet above sea-level, and, according to the *Geological Report of Iowa*, is the highest point in the state.

ANCIENT HYDROGRAPHY.

It is of interest in this connection to notice the indications which are left upon the face of the land of the ancient courses which the waters of the Northwest pursued to the sea. They are discussed in some detail in the pages devoted to the different streams, and here only a general view of the entire field will be taken.

The geological epoch known as the glacial age had much to do in giving to this region its present topography, and particularly in altering the courses of many of the streams to their modern channels. Some of them still pursue their old courses, which they had eroded previous to the deposition of the glacial drift, while others were completely changed in direction, or rather were abolished, the water finding another place of escape.

From the conclusions reached by the different geologists who have studied the subject it may be gathered that, before or during the advance and recession of the ice-cap, almost the entire district under discussion drained into the Mississippi, whose mouth was then near the present mouth of the Ohio river. The valley of the Red River of the North was then occupied by a large lake, which extended far up into the British possessions, and the entire basin of the river, instead of being tributary to Hudson bay, drained in directly the opposite direction along the course of the Minnesota river, which is but a poor representative of the ancient stream, into the Mississippi above the site of Saint Paul. To state it more correctly, the Mississippi entered it there, for the Mississippi above the junction was much the smaller stream of the two.

Then, again, the Mississippi had another important tributary on the east, which the changes of the glacial age transferred to lake Michigan. In the western drainage area of lake Michigan the Wolf and the Upper Fox unite to form the Lower Fox river. Formerly the Wolf, instead of flowing into lake Winnebago, entered the modern valley of the Wisconsin river at Portage City, and so reached the Gulf of Mexico, and this reduced the western drainage area of lake Michigan to a comparatively narrow strip along the lake shore. This narrow area was almost completely covered at one time by the waters of lake Michigan, which rose relative to the land about 200 feet, and even overflowed to a considerable extent up the valley of the Wolf.

Lake Superior, as demonstrated by Professor N. H. Winchell, emptied into lake Michigan by an old channel across the upper peninsula of Michigan, while the topography at the southern end of lake Michigan itself gives evidence that this lake once had an outlet, by way of the Illinois river valley, into the Mississippi, and it is also in place to mention that lake Erie in former days flowed to the Gulf of Mexico by way of the Maumee and Wabash valleys.

From the Red River of the North in the United States and from the Wolf river the Upper Mississippi received approximately the drainage of 45,000 square miles more than is now tributary to it. Hence the ancient drainage area of the Mississippi in Dakota, Minnesota, and Wisconsin was approximately 127,000 square miles, reckoning from modern water-sheds; but it must not be forgotten that during the glacial age water-shed lines were, to a great extent, obliterated in the latter part of that period, great floods of water pouring from the southern extremity of the ice-cap, irrespective of the topography which underlaid the covering of ice.

TOPOGRAPHY AND CHARACTER OF THE COUNTRY.

From the elevations just given for the line of water-shed surrounding the basin of the upper Mississippi it will be seen that there are considerable inequalities in the general surface; yet the extremes of elevation of this crest line do not differ by more than 1,100 to 1,200 feet, and are many miles distant from each other.

Although it is possible to conceive of a mountainous country in which the lines limiting the drainage basins would be comparatively level, yet in the degree of their undulations they generally give some indication of the nature of the topography, as is exemplified in the present case. While there are in places rather abrupt changes of several hundred feet in the level, still Minnesota, Wisconsin, and the surrounding region are not mountainous, but may fairly claim to represent the medium between the mountainous districts of our country and the extensive plains which lie to the westward. In Minnesota especially, which has an area of 83,365 square miles (only 11,000 square miles less than the combined areas of New York and Pennsylvania), there is represented almost every variety, from a rugged surface to a remarkably level prairie.

Taking a general view of the entire region, the highest land may be considered to be in northern Wisconsin and Minnesota, near the shores of lake Superior. From this there is a rapid fall of from 600 to 1,100 feet in 15 to 35 miles to the lake, and a long gradual slope to the south, draining for the most part into the Mississippi river.

LAKE SUPERIOR REGION.

About lake Superior occurs the rugged part of the region we are considering. On the north shore especially are high rocky cliffs and slopes, on the south shore several hill ranges, and in Michigan rocky cliffs; but nowhere is there a truly mountainous section.

COUNTRY SOUTH OF LAKE SUPERIOR.

After crossing the water-shed, and passing southward in Minnesota and Wisconsin, the surface is undulating, and in places almost hilly; but, to a large extent, the streams appear to have carved their channels into the surface without striking topographical features which would seem to have guided them. Following the law of gravitation, they have taken the general southerly slope, and worn their channels through the soil, often into the underlying stratified rock.

In the southern counties of Wisconsin and Minnesota the erosion of the streams has produced bluffs 200 to 500 feet high, and given to the immediate vicinity of the Mississippi and its tributaries a very picturesque appearance; but ascend from the valleys of the streams, and the gently undulating surface is once more seen.

In places, as along the water-shed separating the basins of the Upper Mississippi and the Red River of the North, the undulating surface develops into a marvelous mixture of knolls, ridges, and small hollows, with very little level, except the surfaces of the innumerable lakes. This is the effect of the glacial action, of which mention will be made on subsequent pages. While there are no abrupt changes of elevation of any considerable magnitude away from the vicinity of the great lakes, the rise in the general surface, unnoticeable though it may be, is often of importance, and serves to give activity to the streams.

DISTRIBUTION OF THE TIMBER.

In the northern part of Wisconsin, the upper peninsula of Michigan, and in northern Minnesota, from the east to the headwaters of the Mississippi, occurs the pine, which has made lumbering one of the chief industries of that region.

In northern Wisconsin and Minnesota are extensive tracts of land, consisting of tamarack and cedar swamp, interspersed with a thin pine growth; but in central and southern Wisconsin the pine is more and more replaced by a hard-wood growth, which occurs in groves, gradually becoming less prominent as the prairie region of Illinois is neared. In Minnesota the pine is gradually replaced by hard wood, and this continues toward the south and west in groves, which are finally restricted to the water-courses. Passing down through the center of the southern portion of the state is an exception to this in the "Big Woods", which is a large body of hard-wood timber, forming a peculiar feature of southern Minnesota. To the east, and particularly to the west of the big woods, the timber is very light, and is almost entirely confined to the river bottoms; also southward, in Iowa, the prairie features largely predominate.

PRAIRIE REGION.

It is in the southern, but especially in the western, portion of Minnesota that we find the typical American prairie, and one may travel mile after mile without meeting a tree, unless he descends to the banks of the streams, where may be found a few elms or cottonwoods. Within late years, however, the farmers have planted trees about their dwellings as a protection from the "blizzards", which rage over the country in winter.

While the surface of the prairie is usually rolling in character, along the valley of the Red River of the North it is a level plain as far as the eye can reach, without a tree or rock to break the outline, except along the river, where there is a belt of foliage.

CHARACTER OF THE SOIL.

The soil of the region under consideration exerts a striking influence upon the character of the growth and productiveness. To the varying nature of the glacial drift, which, with its modifications, forms the soil and subsoil of this whole region, with very slight exceptions, is due the division of the country into pine land and prairie, and into comparatively unproductive soil and a ground bearing the richest harvests of grain.

The heavy clay soils, which for many feet in depth cover the southern and western portions of Minnesota and extend westward into Dakota, contain, in almost inexhaustible store, the salts necessary for the successful growth of wheat, and remarkable yields are recorded, especially from the valley of the Red River of the North. In the lower and western portion of Wisconsin also wheat is very successfully raised. On passing into Iowa and Illinois the soil becomes more loamy in character, and is better adapted to the raising of corn, for which those states are noted. Large quantities of winter wheat are also grown in Illinois. In the Northwest the wheat is practically, without an exception, spring wheat; that is, grain sown in the spring. It has a hard shell, and yields a very superior quality of flour.

In northern Minnesota and Wisconsin the soil is lighter, as a rule, and in many places sand is the most important constituent. This is a congenial ground for the pine, and, as a consequence, we have the pine forests, which are fast disappearing through the gang-saws of the mills. The drift is not always homogeneous, and sometimes a sand ridge, covered with pine, will extend far into an area of clay soil, with its hard-wood growth, the distinction being very marked.

Although there are iron mines in Wisconsin, and copper and iron mines in the upper peninsula of Michigan, and although great quantities of lumber are cut, the Northwest is essentially a farming country.

CHARACTER AND DISTRIBUTION OF THE WATER-POWERS.

STREAMS OF THE PRAIRIE REGION.

There is a popular idea that in a prairie or semi-prairie country, like a large portion of that under discussion the streams are necessarily sluggish, and the water-power small, if there is any. It is true that the typical water-course of the prairie is not the bold, dashing torrent of the mountains, but it is equally true that it is not uniformly a meander, which can scarcely draw its slow length along.

The true prairie is not necessarily a level plain. The slope of the general surface is often considerable, and this gives rise to swift water, and even rapids, in the streams, thus affording many available powers. This is the case in the prairie of the Northwest, and, while extensive falls are uncommon, there is a general distribution of moderate water-powers all along most of the streams.

One point to be noted in this connection is that such water-powers are not in inaccessible valleys, with rugged mountains upon either side, hemmed in by high, rocky cliffs, and in a country whose sterile soil yields only a niggardly reward to industry; but they are situated in the midst of one of the most fertile sections of our country, where great fields of grain give promise of work to keep the millstones turning day and night, and where the gently rising banks and facilities of approach afford every advantage for their inexpensive improvement.

The characteristic occupation of the Northwest decides the channel in which the utilization of the water-power shall take its course, and an improved power is not complete until it has one or more flouring-mills converting the wheat raised right at hand into flour, either for home consumption or to supply a distant demand.

By the facilities for communication with other sections of the country crude materials of different kinds can be as readily carried to these cheap powers as the cotton of the southern states has been carried to the looms of New England.

The pine forests have supplied work for some of the largest saw-mills of the world, and poplar, spruce, and pine keep many wood-pulp and paper-mills busy. The hard woods, as oak, hickory, and ash, are used for the manufacture of wagons and tools, to supply the demands of the farming population, and there are many machine tool works. There are comparatively few woolen-mills.

STREAMS OF THE RUGGED REGION.

There are sections of this northwestern region where the country is rough and rugged without being strictly mountainous. These sections are mostly in the northern portion of the district, and the streams are not generally

so accessible as those farther to the south, nor do they lie so directly in the line of eastward traffic; but, with the further development of the country, their importance will become much greater.

In the wild, unsettled region in the extreme northeastern part of Minnesota north of lake Superior, and in sections along the south shore of that lake, there is little demand for water-power, and not much probability of it in the near future, although the Canadian Pacific and Northern Pacific railways may develop that region.

VALUE OF THE WATER-POWERS.

Water-power is now very cheap, and even at the extensively improved sites $10 per year per horse-power is above the average. Good powers may be obtained for $5. In the manufacturing centers of the New England states such rates would be considered extremely low. Many unimproved powers can be had at very moderate rates even for this region, while in some localities the power will be almost given away, the theory being that such improvements will enhance the value of other property. In some localities the people are also very anxious to have a flouring-mill erected for their own convenience, and special inducements are offered. However, powers in favorable localities are generally appreciated, and are held at greater value by the riparian owners.

DISTRIBUTION OF THE WATER-POWERS.

The division into drainage basins has been already given, and the statement made that, considered in a general way, there was a long, gradual inclination toward the south in Wisconsin and Minnesota, draining into the Mississippi, and a more rapid slope northward in Wisconsin to lake Superior, which slope is continued through a portion of the upper peninsula of Michigan. Beside these, there is the drainage toward lake Michigan from Wisconsin, and to the Red River of the North from Minnesota and Dakota, while a portion of Minnesota drains into the north shore of lake Superior.

UPPER MISSISSIPPI BASIN.

The most extensive drainage basin is that tributary to the Mississippi river, and, although the slope is not so great as in other sections, we look there for the greatest manifestation of water-power. The total fall from the extreme sources of the Mississippi to Saint Paul, a distance by river of about 500 miles, is very nearly 1,000 feet. This to a considerable extent is concentrated in rapids, which, with the large flow of the stream, would furnish very fine powers if improved. About 75 feet of fall is concentrated in Saint Anthony's falls and the rapids at Minneapolis, near Saint Paul, and at this place, in a condition of considerable development, is situated one of the finest water-powers of the United States, the total theoretical power, in a fair stage of the river, being estimated at 120,000 horse-power. Railroads run beside this power, and the manufacturing already done gives Minneapolis a high rank among our manufacturing cities. It is said to be the second or third milling center of the world, and only finds its superior in that respect in Germany.

The tributaries of the Mississippi are, many of them, large streams. The Wisconsin, Chippewa, Saint Croix, and Minnesota rivers abound in good powers, especially the upper waters of the Wisconsin—as Grandfather Bull, Father Bull, Little Bull rapids. These powers in northern Wisconsin are mainly undeveloped, except so far as used for saw-mills.

WESTERN DRAINAGE AREA OF LAKE MICHIGAN.

Although the western drainage area of lake Michigan is narrow, there is a peculiar concentration of a large portion of its drainage in one river, the Lower Fox, giving rise to important water-powers, which receive attention upon a later page. The thriving city of Appleton is situated upon one of these, and to its well-developed water-power is chiefly due its prosperity.

North of the Lower Fox river, into Michigan, there is a considerable descent in the streams, and in the upper peninsula of Michigan these streams are of small size, the Ontonagon and Escanaba rivers having the largest drainage areas. But many of these rivers have considerable fall in their passage, either to lake Superior or to lake Michigan, and are, to a great extent, in a wild, unsettled section of country. They are small, but from their rapid descent the amount of water-power is large. As may be gathered from preceding remarks, the country is undeveloped and this power unused, but some of the rivers, from their location, are of prominence. Especially is this true of the largest, the Saint Louis river, which will receive attention on the following pages.

BASIN OF THE RED RIVER OF THE NORTH.

The Red River of the North is entirely a prairie stream. Upon its upper waters are several fine powers, one having a total fall of over 80 feet. The water-power is practically limited to the upper portion of the stream and its tributaries.

STREAMS OF THE WESTERN PORTION OF LAKE SUPERIOR.

There are in the extreme northern part of Minnesota several streams flowing into the chain of lakes and marsh land which connects the Lake of the Woods with lake Superior. Some of these streams are rapid, and

must have a considerable fall. The Vermillion river, as described in Dr. Owen's report, has several sharp rapids in its course, and the outlet of all this basin toward lake Superior, the Pigeon river, has many heavy rapids and falls; but this region is hardly explored as yet, and is entirely undeveloped. The Lake of the Woods has also a connection with lake Winnipeg, in Manitoba, by the Winnipeg river, and hence the drainage of northern Minnesota is not capable of exact calculation. In view of this fact, the 15,965 square miles represented as draining into the north shore of lake Superior cannot be considered as entirely tributary to that body of water. The Winnipeg river is stated in one report to have a fall of 349 feet in its length of 165 miles. This places the Lake of the Woods 1,050 feet above the sea and 450 feet above lake Superior. In one place Winnipeg river is called White river, from its foaming rapids.

GEOLOGY OF THE REGION IN ITS BEARINGS ON THE WATER-POWERS.

CAUSE OF THE FORM OF THE DRAINAGE SYSTEM.

The details of this subject are treated to some extent in describing the several water-sheds, but a general view of the entire region from a geological standpoint cannot be out of place, especially as rivers derive their characteristics in such an important degree from the condition of the rock and loose material over which they run. It has been observed that, viewed in a broad sense, there is a comparatively abrupt inclination toward lake Superior, and in Wisconsin and Minnesota a long, gradual dip southward, which determines the main features of the system of drainage of that region.

It is well understood that, subsequent to the formation of the Archaic rocks, a succession of seas, or of advances and recessions of the same sea, deposited the stratified rocks of the succeeding periods of time.

The old Silurian ocean which washed the shores of the Archæan land deposited as it receded the Potsdam sandstone, the Saint Peter's sandstone, the lower magnesian limestone, depositing its sediment upon this old Archaic continent. It was a natural consequence that the successive superimposed strata should take the slope of this ancient rock, which formed the bed of the primeval ocean, and as each succeeding sea had its shore line upon the lately-formed rock, so also each stratum, as seen at the present day, has its line of outcrop upon the preceding one.

In the North American continent a belt of the Archaic land runs through Canada, a spur forming the Adirondacks in the state of New York, and this belt of primitive rock continues west through the upper peninsula of Michigan, northern Wisconsin, and central Minnesota, where it outcrops, with a dip southward through those states. The sedimentary rocks were deposited upon this Archæan base, taking its southerly dip and outcropping in successive belts, which are crossed in going from north to south in their successive order of deposition.

Although much complicated by erosion and otherwise, these geological conditions exist to the Gulf of Mexico, where the late Tertiary deposits are now being overlaid by the alluvium of the modern age. The lake Superior slopes are inequalities in the surface of the Archaic rock, and are due to upheavals.

Thus we see the origin of the existing drainage system. The streams in ancient days, as at present, finding the general surface dipping toward the south, flowed southward, and the glacial action, and the changes accompanying it, did not materially alter their courses, with the exception of the cases mentioned under the first division of these remarks.

GLACIAL AGE.

To the action which took place in the glacial age is due, in a very marked degree, its modern surface features. In treating of the Red River of the North the history of the glacial age is given to some extent. Suffice it to say here that a solid mass of ice, thousands of feet thick, forced its way south, grinding up the soil and rock surface, and in its recession left the *débris* as glacial drift all over the surface, with the exception of a small area in the region about southwestern Wisconsin. This drift, sometimes modified by subsequent action, consists of clay, sand, gravel, and bowlders in varying proportions, and forms, almost without exception, the soil of the entire region. The streams have worn their channels in it, and some are already down to the underlying rock, while others have not yet succeeded in wearing through the surface-covering of drift, in some places from 200 to 300 feet thick.

ORIGIN OF THE MINNESOTA LAKES.

These lakes, which form such a peculiar feature in northwestern scenery, are due to the ice age. With very few exceptions, they lie in hollows left in the drift when it was deposited. The theory is that the ice-cap held on its surface and in its mass vast accumulations of drift, which were deposited as it melted in irregular heaps and ridges, the hollows left being filled with water until an outlet was formed.

RELATIVE INFLUENCE OF METAMORPHIC AND SEDIMENTARY ROCKS ON THE STREAMS.

Many of the streams flow entirely or in part over the metamorphic and igneous rock of the Archæan belt, and such streams have usually sharp rapids along their courses, instead of a more uniform descent.

The hard nature of the rock resists erosion better than the sedimentary rocks over which the streams flow further south. It must not be understood, however, that there are no rapids or falls over the sedimentary rocks. There are many falls, due to the passage of a stream from a hard layer to a soft underlying one, and numerous rapids on the hard layers of limestone rock. All the rapids of the Lower Fox river are over the Trenton limestones, and the falls of Saint Anthony are caused by the superposition of the Trenton limestone on the soft Saint Peter's sandstone. Even in the drift moderate rapids occur where there are accumulations of bowlders, and, as might be expected, the beds of the streams are worn much deeper below the general surface in the region of sedimentary rocks than where the Archæan rock underlies the soil.

FLOW OF THE STREAMS AND CONDITIONS AFFECTING IT.

IMPOSSIBILITY OF ACCURATE CALCULATIONS.

The primary requisite for a stream of water is the rainfall; but while this is so evident, it is hardly correct to say that the discharge from a given area depends on the rainfall upon that region. The flow of the streams which drain the surface of the land depends so much upon the topography, the character of the soil and underlying rock, the temperature and winds, and the storage capacity, that it is impossible to determine any definite ratio between the discharge of streams and the annual precipitation. The most that can be done is by experiment, observation, and calculation to find, as nearly as possible, the effects which the different circumstances met with in nature have upon the waters of the earth in making their circuit between the clouds and the sea.

It is the object here to consider the conditions affecting the flow of the rivers of the Northwest.

AMOUNT OF AQUEOUS PRECIPITATION.

First, the annual precipitation is not so great upon these inland states as upon those bordering the ocean. The heaviest precipitation upon the area under discussion averages about 35 inches, while the lightest does not exceed 15 inches per annum. This is, of course, to the detriment of the water-powers; but it is offset to a large degree by other considerations, as will presently be noticed. The diminution in the precipitation is general from east to west, with local variations, perhaps owing to the proximity of the great lakes. In the upper peninsula of Michigan and northeastern Wisconsin the annual precipitation averages at least 35 inches; around lake Superior, 30 to 35 inches; and upon the upper waters of the Mississippi and the sources of the Red River of the North, 25 inches, which is the amount used by the United States engineers in making calculations for the reservoir system on the upper Mississippi. From the sources of the Red River of the North westward the amount of annual precipitation rapidly falls down to 15 inches, or even less in Dakota. Most of the rain and snow of this region appears to be due to the condensation of the moisture in the warm currents of air which sweep up the valley of the Mississippi from the Gulf, and the sudden decrease of moisture at the eastern portion of Dakota marks the margin of the main effects of these vapor-bearing Gulf currents.

CLIMATIC EFFECTS.

The high northern latitude causes cold winters, but the summer temperature is much influenced by the warm air from the Gulf of Mexico. In the far Northwest the climate is very much modified by the softening influence of the Japan current in the Pacific ocean, whose effects are felt even in Dakota, tempering the winter climate to a great extent.

The temperatures given below are averaged from the report of the Smithsonian Institution. More detailed tables are furnished on succeeding pages. For the basin of the Red River of the North in the United States the summer temperature averages 65 to 70 degrees, and the winter temperature 8 to 10 degrees Fahrenheit above zero. The temperature about the sources of the Mississippi is about the same. On the western drainage area of lake Michigan the average summer temperature is 68 to 70 degrees, and the average winter temperature about 20 degrees Fahrenheit above zero. This large difference of 50 to 60 degrees between the average temperatures for the two extreme seasons of the year, together with the fact that the winter winds are more generally dry winds from the northward than those of summer, must exert considerable influence upon the distribution of the precipitation throughout the year.

Turning again to the report of the Smithsonian Institution, and selecting characteristic data, we find these results:

DISTRIBUTION OF ANNUAL PRECIPITATION, IN INCHES.

Region.	Locality.	Spring.	Summer.	Autumn.	Winter.	Total.
Basin of the Red River of the North	Fort Ransom, Dakota	5.14	4.96	3.38	1.82	15.30
	Breckinridge, Minnesota	5.41	12.05	3.17	2.45	23.08
Western drainage area of lake Michigan	Appleton, Wisconsin	7.65	10.24	6.92	3.70	28.51
	Embarrass, Wisconsin	8.14	12.49	8.21	5.73	34.57

TIMES OF FRESHET AND DROUGHT.

Of all four seasons the summer has the heaviest precipitation and the winter the lightest, almost exclusively consisting of snow. On this depends one important feature of the streams, viz: the June freshets. But the effect of the cold winter temperature is not confined to the distribution of the precipitation. After it has reached the earth, the icy grasp of winter, to a large extent, holds the moisture fast until the warmer air of April and May releases it, and then there is a spring freshet, caused by the melting snow and ice.

The fall rains, which are relied upon to fill the springs for the winter's flow, often produce high water in the streams. In normal years the low water takes place in late summer and early autumn, before the rains of fall have replenished the streams, and in winter, when the sources of supply are to so large an extent frozen solid. It is evident that the cold winter must have an injurious effect upon the steadiness of flow, which is not experienced to nearly so great an extent by the southern rivers. Those streams have in this respect the advantage of the northern water-courses, but it will be shown how the injurious influence of the cold winters is remarkably counteracted.

EFFECTS OF MOUNTAINOUS AND OF LEVEL COUNTRIES.

In a rocky, mountainous country, where the only level land is the narrow flat at the bottom of the valley, the rain, as soon as it falls, rushes immediately down the mountain side and is wasted in sudden floods—a state of affairs most inimical to the interests of water-power; and it is largely from this cause that in the New England states the creating of artificial reservoirs becomes such an important item in the improvement of them. In the Northwest the case is, to a certain extent, just the opposite. The tendency is for the rain to soak into the ground and gradually find its way to the water-courses; and hence what would be in the one place a disastrous flood is here distributed through several days, or even weeks, and gradually disappears.

The only streams we have dealt with that in this respect at all resemble the typical mountain stream are some of those discharging into lake Superior; but even with these the effect of rocky, steep drainage is much mitigated by level lands upon their upper waters. There are also some streams in the comparatively level prairie which are very unsteady, but these are hardly more than drains for the surface water, and, not being fed by springs or lakes to any extent, cannot be taken for comparison.

INFLUENCE OF SAND AND GRAVEL BEDS.

The drift, as has been described, is very irregular in character, and where the clay is replaced by sand and gravel the absorption of the moisture is very great. This seriously diminishes the flow of the streams in the immediately locality, but, nevertheless, is often of great value in maintaining the flow at some other place, for the water issues in copious springs at a lower point. Thus, on the south shore of lake Superior there is an extensive sandy ridge upon which there are no streams, but at its base are a large number of beautiful springs of clear running water, which feed the Bois Brulé and neighboring rivers, often bubbling up from the sandy bed of lakes. In northern Minnesota, also, there are sand ridges exerting their influence upon the rivers there. In scarcely any place can this effect of sand ridges be more marked than in the state of Mississippi, where the sand-hill streams often have a mill within a few rods of their source, and are an unfailing source of moderate power throughout the year.

In some localities it is difficult to see how this absorptive power of sand and gravel beds can have any effect but positive injury upon the water-powers, as the water-bearing layers strike too low to feed the rivers in the water-power regions.

For example, the valley of the Red River of the North is underlaid by water-bearing beds, which receive their supply from where they outcrop on each side of the river and within its basin. The result is that water which would otherwise flow into the tributaries of the main river is carried down beneath the river bed, and, if returned at all to the stream, it is far below the region in which its water-powers are situated. Several fine artesian wells in the valley are fed by this storage.

INFLUENCE OF FISSURED ROCK.

The old Archaic rock which underlies the soil over so large a portion of the Northwest is hard and solid and impervious to water; but the newer formations are not so resistant, and to them some loss is doubtless due. Thus, there are many artesian wells in eastern Wisconsin which get their supply from the rocks, which there have a southeastern dip. Water percolates from the outcrop down through fissures, and probably a considerable amount thus finds its way to lake Michigan underground without ever entering the legitimate surface channels. At many places along the Mississippi valley are artesian wells, fed by water drained in this manner from the surface streams. What effect this has in reducing the flow of the streams it is impossible to determine, but that it exerts some influence is self-evident.

ACTION OF WOODLAND.

The woodland which yet covers so large a portion of Wisconsin, Minnesota, and Michigan cannot but be of value in steadying the flow of the streams. The grasses, roots, and decaying vegetation of a forest retard the escape of water, while the shade also prevents excessive evaporation. It must not be overlooked that trees, in growing, take up and dissipate an enormous amount of moisture, which is returned as rain, but is kept from reaching the streams. This very action, however, in making the distribution of the precipitation more uniform, would have a tendency to equalize the flow of the streams, and the universal testimony throughout cleared countries which were once well wooded is to that effect. Sir Gustav Wex, in a treatise on the subject, bears testimony to this result from the cutting of the European forests; the older of our states testify to it; and even in Ohio, which has been settled almost within a half century, the complaint is almost universal among the millers about the change for the worse in the steadiness of many of the streams. There the cause is largely the draining and plowing of the land, whereby the water reaches the creeks in a much shorter time than when the land is marshy and overgrown with thickets.

EFFECTS OF PRAIRIE CULTIVATION.

In some prairie regions, however, the effect of cultivating the land has been very different; drains have made marshes and areas of land tributary to the streams where evaporation formerly took all the water which did not sink into the soil, and some streams have been very materially increased in their volume by this means, as well as improved in their uniformity of flow.

In Kansas the curious result of farming has been to increase the rainfall. The theory is that the breaking of the tough prairie sod makes the soil more pervious to moisture, and hence immediate surface discharge is decreased, absorption and evaporation are increased, and consequently the rainfall is augmented.

LAKES OF THE NORTHWEST.

It has been said that the injurious effects of the cold climate upon the streams in diminishing their discharge are remarkably counteracted, and surely a glance at the map will satisfy all familiar with the effects of lakes of the truth of this statement.

If natural reservoirs are of any value in regulating the flow of streams, certainly the rivers of the Northwest must be extremely steady. A very large portion of Wisconsin and of Minnesota, but especially of the latter state, is almost literally covered with lakes, varying in size from the smallest pond to bodies of several hundred square miles in extent. The map of the lake region of the Red River of the North will serve to illustrate this. A count from large and detailed state maps of Minnesota and Wisconsin, and from the land-office maps of Dakota and the upper peninsula of Michigan, gave these results.

DISTRIBUTION OF LAKES ACCORDING TO STATE BOUNDARIES.

	Number.
Minnesota	4,920
Wisconsin	2,465
Upper peninsula of Michigan	523
Eastern Dakota	133
The entire region under discussion	8,041

DISTRIBUTION ACCORDING TO DRAINAGE BASINS.

UPPER MISSISSIPPI RIVER.

Minnesota	3,817
Wisconsin	1,859
Dakota	46
North of the Northern Pacific railroad	954
West side of river and south of Northern Pacific railroad	2,023
East side of river and south of Northern Pacific railroad, in Minnesota	420
Total in Minnesota, Wisconsin, and Dakota	5,256

	Number.
RED RIVER OF THE NORTH.	
Minnesota	700
Dakota	87
Total in Minnesota and Dakota	787
RAINY LAKE REGION AND NORTHERN SHORE OF LAKE SUPERIOR.	
Minnesota	365
SOUTHERN SHORE OF LAKE SUPERIOR.	
Wisconsin and Minnesota	186
Michigan	164
Total in Minnesota, Wisconsin, and Michigan	350
WESTERN SHORE OF LAKE MICHIGAN.	
Wisconsin	438
Michigan	359
Total in Wisconsin and Michigan	797

DATA CONCERNING THE LARGER LAKES.

Drainage basin.	Lake.	Locality.	Area.	Drainage area.*
			Sq. miles.	*Sq. miles.*
Upper Mississippi	Mille Lacs	Minnesota	186	226
	Leech lake	do	176	1,238
	Lake Winnibagoshish	do	68	1,350
	Cass lake	do	34	1,008
Western shore of lake Michigan	Lake Winnebago	Wisconsin	199	6,046
Red River of the North	Red lake	Minnesota	250	2,149
	Otter Tail lake	do	20	1,442
Rainy lake region and northern shore of lake Superior	Lake of the Woods	Minnesota and the British possessions	†954	
	Rainy lake	do	234	
	Vermillion lake	Minnesota	59	536

* Including water surface.

† This is less than the true amount, as the extreme northern extension of the lake was not represented upon the map from which the measurement was taken.

The maps show that by far the greater number of these lakes are about the headwaters of the rivers, and hence their effect in regulating the flow is much more general than if they were distributed farther down stream. If it were not for the immense number of natural reservoirs these streams would be very unsteady.

COMPARISON OF LAKELESS WITH RESERVOIR STREAMS.

We are not without cases whereby we may judge of what the conditions of the water-powers would be did not these lakes dot the surface of the land. In Dakota there are comparatively few lakes, and the streams are very unsteady, the headwaters of many of them literally freezing solid in winter. It is true that the precipitation is much less there; but, allowing for the difference in rainfall, a simple calculation shows that the ordinary low-water discharge is only about 20 per cent. of what it would be were the topographical conditions similar to those in the lake region to the eastward in Minnesota. This calculation is made on the assumption that the evaporation bears a constant ratio to the amount of precipitation, which is not strictly correct; but the result serves to give an idea of the effects produced by the lakes. As was just mentioned, the discharge per square mile of the lakeless regions is sometimes reduced absolutely to zero at the headwaters of the streams.

The influence which the lakes exert cannot be better illustrated than by the estimates of the ordinary low-water discharge per second per square mile of drainage area for different places along the Red River of the North, as given in the table at the close of the section devoted to that river.

The remarks preceding the tables explain their peculiarities. The tables are derived from a comparison of the upper Mississippi above Saint Paul and of the Red River of the North at the crossing of the national boundary-line. It must be borne in mind that the sources of the Mississippi abound in lakes, while, except at the extreme headwaters, the Red River of the North has comparatively few lakes. The very light rainfall over a large portion of the basin of the latter stream would also account for much of the difference in the nature of the two rivers.

River.	Area drained.	Estimated ordinary low-water flow per second.
	Square miles.	*Cubic feet.*
Red River of the North at the national boundary	39,577	2,800
Mississippi river at Saint Paul	36,741	About 7,000

The ordinary low-water discharge of the Mississippi at Saint Paul is more than twice that of the Red River of the North at the national boundary, while the area tributary to it is 3,000 square miles less. The following estimates of the ordinary low-water discharge for several of the streams of the Northwest were obtained mostly by comparing actual gaugings with the drainage areas. Of course they are liable to error, due to not making the gaugings at a strictly ordinary low stage of the river, but they are believed to be approximately correct. In the case of the Menominee and the Saint Louis rivers, where no actual measurements were obtainable, the discharge was estimated by comparison with neighboring streams. Both these latter have the greatest precipitation of the entire region upon their basins:

River.	Locality.	Estimated ordinary low-water discharge per square mile of drainage area.
		Cubic feet per second.
Red River of the North	Mouth of the Pelican river	0.416
	Breckinridge, Minnesota	0.217
Mississippi	Aitkin, Minnesota	0.340
Lower Fox river	Foot of lake Winnebago	0.413
Saint Louis river	Mouth of river	0.400
Menominee river	do	0.460

Mr. G. F. Swain, special agent of the census, who has written a report upon the water-power of the Atlantic states, kindly furnishes the following information:

The ordinary low-water flow of the streams of the Atlantic coast without reservoirs, which have a rainfall of 50 inches per year, rarely exceeds 0.40 of a cubic foot per second per square mile of drainage area, while some with 38 to 40 inches of rainfall give only 0.30 of a cubic foot per second in the same stage, as is the case with the Potomac river.

In the lake region of the Northwest, with a precipitation of less than 30 inches per annum, the ordinary low-water flow exceeds in some cases 0.40 of a cubic foot per second per square mile of drainage area.

What speaks more eloquently for the lakes of the Northwest than these figures? When a stream like the upper portion of the Red River of the North is observed year after year, and is seen to scarcely vary four feet in depth from the drought of summer or the chilling cold of a northern winter to the melting of the snow and ice in spring, and when one is told that a three-feet rise on the beautiful river of the Lower Fox is unusual, then it is that the true value of the lakes is appreciated.

INFLUENCE OF SWAMPS.

In giving credit to the lakes we must not forget the influence of the swamps, which are mingled with them in northern Wisconsin and Minnesota, in maintaining the flow of the streams. The moisture retained by the roots and thick, matted growth is dealt out gradually. It cannot be denied, however, that the action of the swamps is not entirely beneficial. The evaporation from their luxuriant vegetation and the shallow, stagnant pools of water is enormous, while in cold winters they often freeze entirely solid, and then the flow from them ceases completely. For example, a person familiar with the Kankakee river, in Illinois, stated it as his opinion that the swamps at the headwaters of that river were of more injury than good to the stability of the flow. It is probable that in a moderately level country, with a rigorous climate, swamps alone are of questionable value where a permanent water-power is required throughout the year; but deep-seated springs, where they exist, exert a greater influence in regulating the flow. With lakes the case is different. It is true that extensive evaporation takes place from their water surfaces—about 0.15 of an inch per day from April to October, inclusive, at the sources of the Mississippi—but their depth, as compared with their surface, is much greater than in swamps, and they usually receive the drainage from considerable areas, which is protected in their depths from evaporation; also in winter a covering of ice (three to four feet in Minnesota in the winter of 1880–'81) protects the waters below from freezing, and thus a constant supply is given to the streams throughout the coldest weather.

CLASSIFICATION OF THE LAKES.

It must not be supposed that each one of the lakes in the region engaging our attention is filled to the brim by full-flowing streams, while a small river rushes through its outlet. From the very fact of their proximity to each other, the drainage areas of many must be extremely small; in fact, some have hardly more area tributary to them than the water surface which they expose to the rain and snow. Such lakes usually constitute a separate system of their own, and are of no value to the main stream in whose basin they lie. Other lakes receive a supply of water which is greater than their loss from evaporation and filtration, and these pour their tribute into the water-courses.

The lakes of the Northwest may be divided into three classes: 1. Those lying in the course of the main streams, being in a certain way expansions of their surface. 2. Those which have an outlet into the main streams. 3. Those without any visible outlet.

FIRST CLASS.—To this class many of the important lakes belong, serving a most useful part in catching the surplus water of the streams and parting with it gradually, and often there are side streams and lakes directly tributary to them. In this connection it is proper to mention a peculiarity of some western streams, viz, in having lakes tributary to them which are connected by a short, sluggish channel with the water of the river. When the main stream is high, the water backs up in this short channel and fills the lake, to be let out gradually. Lakes which thus equalized the flow were called, in the language of the Chippewas, *Pokegama*, and several pokegamas will be noticed upon the maps of Minnesota and Wisconsin.

SECOND CLASS.—Of the second class of lakes, some give large additions to the volume of the rivers, while the outlets of others are only small brooks. No correct estimate of the importance of these lakes to the maintenance of the flow of the rivers can be gathered from their actual size; the extent of the area tributary to them must, of course, be taken into account. The following example illustrates this point: Mille Lacs, in Minnesota, has an area only 13 square miles less than that of lake Winnebago, in Wisconsin, as shown by the figures in the table; but the area tributary to lake Winnebago is 6,046 square miles, while the line of water-shed limiting the drainage area of Mille Lacs is nowhere more than 6 miles from its shores. The result is that the broad channel of the Lower Fox is the outlet of the one, and the comparatively small stream of the Rum river drains the other.

LAKES WITHOUT INLETS.—Some of the lakes have a running stream leading from them, but on making their complete circuit no apparent inlet can be discovered. The surface drainage from the surrounding shores is insufficient to account for this. They are fed by springs in their beds, which beds are almost without exception in the glacial drift, which often contains layers of sand and gravel. To the presence of these water-bearing strata is doubtless due the existence of the springs.

A land surveyor informed me that while his party was surveying in western Minnesota in the winter they came to one of these lakes, and, noticing in the distance a singular round hole in the otherwise unbroken ice surface, they went out to examine it. One of them, being too curious, broke through the edge, but managed to hold to the ice until assistance came, the force of the current of water being so great as to hold him out horizontally. This place was far removed from where the current at the outlet could have any effect.

THIRD CLASS.—Of the third class of lakes there is an immense number. Often they are small ponds, filling hollows in the land, but some of them are of considerable extent. There are two causes, one or both of which may operate to produce them, and these give rise to a secondary division of the third class, viz: 1. Lakes having no outlet. 2. Lakes having a subterranean drainage.

To division 1 belong the lakes which have been already alluded to as having very small drainage areas. The supply of water which they receive does not suffice to raise their water surface high enough for them to find an outlet (except perhaps in very wet seasons, when they come for the time under the second class), and they are really stagnant pools, in which the surface is lowered by evaporation. They merge into marshes and reed swamps, such as are found in large numbers in portions of northern Iowa. These lakes, of course, contribute little to the value of the water-powers.

Division 2 takes by far the greater number of the lakes of the third class, and as the water is usually comparatively pure, although the soil is rich in salts, it is fair to conclude that there are very few of them with absolutely no outlet, the same causes that have been mentioned as giving rise to springs in the lake beds acting equally as well to give a means of outlet to the lakes. It is extremely probable that many lakes which apparently have no connection with the streams feed them with a steady supply of water, which filters down through the sand and gravel, where these occur in their beds and banks. There are many probable examples of this. The area of lake Minne-wa-kan, in Dakota, is 107 square miles. Although this lake is claimed to have no outlet, it is thought to aid the volume of the Sheyenne, a tributary of the Red River of the North. In some cases the filtration may take place and the water be discharged at some distant point, thus being a positive source of loss to the volume of the streams of the locality. Nevertheless, it is fair to assume that most of the northwestern lakes exert a beneficial influence upon the water flow of that region; certain is it that their entire absence would make a great difference in its steadiness.

In many cases it is entirely practical to raise the level of the lakes by dams at their outlets, and thus largely increase their storage capacity. The discharge could then be regulated at pleasure, and the permanency of the water-powers still improved. No surveys with this object in view have been made so far as known, with the exception of those carried on under the direction of Major Charles J. Allen, corps of engineers, U. S. A., for the reservoir system of the Upper Mississippi river, and a survey along the Rock river of Illinois for the same purpose. These demonstrate the feasibility of establishing artificial reservoirs upon the Upper Mississippi, which would much improve its navigation and be of great value to the water-power interests. The small cost of land makes artificial reservoirs comparatively inexpensive.

GRADUAL FILLING OF THE LAKES.

It is the inevitable tendency for the decaying vegetation gradually to fill up the lakes, changing them into marshes and peat-bogs. All the different stages in the process, from the open lake to the bed of peat, are now to be seen.

SUMMARY.

Reviewing the preceding pages, before taking up the detailed discussion of the different drainage areas, the prominent facts are briefly these:

1. The region under discussion embraces Minnesota, Wisconsin, the upper peninsula of Michigan, and the northeastern portion of Dakota. In this section of country the main system of drainage is toward the south, being comprised in the basin of the Upper Mississippi, and around this, to the northeast and west, are lesser systems, draining north and east.

2. The country is mainly undulating, but there are considerable changes in the elevation of the general surface. The main features of this change are a long, gradual slope southward, with a short, comparatively sharp declination toward the great lakes. There are, of course, many local modifications of this.

3. As a natural consequence of the facts given in sections 1 and 2, the largest streams are in the Mississippi basin, but the most rapid ones are in the drainage areas surrounding it. It will not answer, however, to consider all of one class sluggish and of the other rapid; the distinction is only a broad one.

4. Because of the condition mentioned in section 3, the actual water-power is quite generally distributed throughout the entire region. The idea that there is no water-power in the prairie is an erroneous one.

5. The great difference between the summer and winter temperatures, and the prevalence of dry winds during the latter season, have the effect of causing an unequal distribution of the aqueous precipitation throughout the different seasons. The cold of winter freezes solid until late in the spring great amounts of water, which in a southern climate would go to maintain the winter flow of the streams.

6. The level nature of the country, as compared with a mountainous region, and the woods, where present, tend to equalize the discharge of the streams through the different seasons, but especially is their uniformity of flow due to the unrivaled system of natural reservoirs furnished by the lakes of the Northwest. These, to a great extent, counteract the effect of the winter's cold in decreasing the volume of the streams.

7. The Northwest is comparatively a newly-settled region, and large tracts of land are yet in their wild state; hence many water-powers are at present of little value because of their location. The easy access to almost all sections of the country, and the rapidity with which the population is increasing, will soon bring these water-powers mostly into use; and the ease with which railroads can be built directly to them, and the fact that so many of them lie in the midst of a region of great natural resources, give to them a special value for the future. At present, water-power can be bought or leased at extremely moderate rates.

THE WESTERN DRAINAGE AREA OF LAKE MICHIGAN.

GENERAL REMARKS.

From south to north the length of the drainage surface is 350 miles. At the southern end it is a mere strip of land, averaging about five miles wide, and in some places scarcely three miles. At the southern end of lake Winnebago the water-shed suddenly turns west, and after reaching the center of the state of Wisconsin, 100 miles west of lake Michigan, it again runs nearly parallel with the lake. At the south, in the neighborhood of Chicago, the water-shed is only slightly elevated above the lake-level; but as it passes north through southern Wisconsin it gradually rises to 100 feet, then 200 feet, and at the point where it takes its bend westward it is from 400 to 500 feet above the lake. Near its extreme western extension, at Portage, in Columbia county, the line of water-shed passes through a sandy plain scarcely elevated above the Wisconsin river, which belongs to the Mississippi system. It is there only about 230 feet above lake Michigan. From Portage north it gradually rises, so that where it crosses into the upper peninsula of Michigan the elevation is somewhat more than 950 feet above the lake. At the most northern point, where the waters of the Menominee extend so far toward lake Superior, the elevation of the crest is nearly, if not quite, 1,000 feet.

Green bay, an arm of lake Michigan on the west, intercepts all the streams in the northern portion of the region under consideration, and the trough in which it lies continues clear across the drainage area in a northwest direction, drawing off a large part of the flow in that section. In reality, the western drainage area of lake Michigan may be considered in two sections:

First. The area tributary to lake Michigan directly, which is the narrow strip extending from the southern end of the lake along the east shore of lake Winnebago, and then northeast on the peninsula between Green bay and lake Michigan.

Second. The area tributary to Green bay.

On account of its being so closely identified with the lake Winnebago basin it has been thought best to discuss the physical geology of the region in the section devoted to the Lower Fox river.

Stated briefly, the facts, as gathered from the state geological reports of Wisconsin, are that the slope of the old underlying rock of the state is southeast, and the overlying strata also slope southeast; hence the general direction of the drainage is southeast.

The Green Bay valley extends southwest across the drainage area and intercepts most of the flow before it reaches lake Michigan. This valley owes its existence to the dip of the strata, the varying hardness of the different kinds of rock, and the action during the glacial epoch of the ice-cap.

The section directly tributary to lake Michigan is widest opposite lake Winnebago, where it averages about thirty miles across, and it is there that the chief streams occur. These are the Milwaukee, the Sheboygan, and the Manitowoc rivers, with drainage areas of from 500 to 800 square miles each. Their headwaters rise near lake Winnebago, 300 to 400 feet above lake Michigan. The streams of the northern and southern portions of this section are necessarily unimportant, from the limited area which they drain.

The section indirectly tributary to lake Michigan through Green bay contains the large streams of eastern Wisconsin, the principal of which are the Upper and Lower Fox and the Wolf rivers, comprising the lake Winnebago system, and north of these are the Oconto, Peshtigo, and Menominee rivers, and in Michigan the Ford and Escanaba rivers.

The northern portion of the section west of lake Michigan is comparatively undeveloped, and the water-power is unused, with inconsiderable exceptions. All of the streams have rapids and many available sites, which will undoubtedly be improved in the future.

South of Green bay the country is more settled, and, as a consequence, the water-power has been to some extent developed. The fine series of powers along the Lower Fox river, which are prominent among those of the Northwest, lie in this region.

AREAS OF DRAINAGE BASINS.

		Square miles.
Milwaukee river		831
Sheboygan river		738
Manitowoc river		553
Lower Fox river:		
Upper Fox river	1,672	
Wolf river	3,763	
Lake Winnebago	611	
Lower Fox river below lake Winnebago	403	
		6,449
Oconto river		1,017
Peshtigo river		1,123
Menominee river		4,113

BASIN OF THE LOWER FOX RIVER.

Interest naturally centers in the Lower Fox drainage basin, because of its size and valuable water-powers, and to the discussion of these much of the space allotted is devoted. The upper waters of the basin are not remarkable for power. The Wolf river, although it is rapid in its upper part, has little fall in its bed below Shawano; the Upper Fox is likewise a sluggish, idle stream; and all the waters of a section of 6,046 square miles are gathered into lake Winnebago without any remarkable water-powers resulting. But lake Winnebago is nearly 170 feet above Green bay, and the flow from this large drainage surface must descend that height in a distance of about 35 miles. The waters are gathered in lake Winnebago, stored in that large reservoir of nearly 200 square miles area, and then sent speeding down the rapids to Green bay, and thus the power which would otherwise be scattered over a large area is here concentrated, where it can be completely used.

MENOMINEE RIVER BASIN.

The Menominee River basin is the next both in size and importance, although it is in a wild, unsettled region of country. From sources to mouth it descends about 950 feet, and many rapids and falls are the result. The drainage area of 4,113 square miles supplies a goodly volume of water, and many fine powers are awaiting development.

A description of this river is given in its proper place.

The Oconto and Peshtigo rivers likewise have a rapid descent, and, although much smaller than the Menominee, give rise to water-powers of value.

RECORDS OF PRECIPITATION AND TEMPERATURE FOR THE WESTERN DRAINAGE AREA OF LAKE MICHIGAN.*

Place.	Spring.	Summer.	Autumn.	Winter.	Year.	Length of observations.	Summer temperature.	Winter temperature.	Length of observations.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*		° ′	° ′	
Waukesha	5.32	10.30	6.92	3.15	25.92	Mar., 1856, to Nov., 1856	69 78	20 75	Mar., 1856, to Mar., 1859.
Milwaukee	8.67	10.07	7.67	5.13	31.54	Jan., 1841, to June, 1877	67 02	24 00	Jan., 1837, to Dec., 1870.
Manitowoc	6.83	10.73	7.06	5.14	29.76	Feb., 1858, to Dec., 1874	65 30	23 72	Oct., 1851, to Dec., 1870.
Wautoma	5.50	6.25	1.98	3.16	25.92	Jan., 1871, to Dec., 1874	.....	.....	
Fort Winnebago	5.58	11.46	7.63	2.83	27.50	Aug., 1836, to Aug., 1845	68 24	19 81	Jan., 1829, to Aug., 1845.
Weyauwega	6.74	17.85	14.23	5.31	44.13	Mar., 1861, to Dec., 1873	68 18	19 32	June, 1860, to May, 1867.
Waupaca	5.50	14.50	6.92	3.93	25.92	Jan., 1867, to Apr., 1874	70 17	20 48	Dec., 1863, to Dec., 1870.
Menasha	6.83	10.73	7.06	5.14	29.76	Oct., 1857, to Mar., 1858	65 30	23 11	Oct., 1857, to Mar., 1858.
Appleton	7.65	10.24	6.92	3.70	28.51	Jan., 1856, to Apr., 1871	67 48	20 15	Jan., 1856, to May, 1870.
Green bay	6.18	9.35	10.43	4.46	32.42	June, 1858, to Sept., 1865	68 10	18 62	May, 1858, to Sept., 1865.
Embarrass	8.14	12.49	8.21	5.73	34.57	Jan., 1864, to Dec., 1874	66 82	18 25	Oct., 1856, to Dec., 1870.
Wausau, on the Wisconsin	6.19	10.30	7.02	3.15	25.92	Feb., 1859, to July, 1859	69 68	17 46	Nov., 1858, to Dec., 1859.
Sturgeon bay	5.87	9.66	8.27	5.01	28.81	Feb., 1870, to June, 1874	68 22	19 14	1870.
Escanaba, Michigan	8.52	13.72	10.57	3.28	36.09	Oct., 1872, to June, 1876	.....	.....	

*Obtained from the publications of the Smithsonian Institution.

DISTRIBUTION OF THE PRECIPITATION.

The annual precipitation on the western drainage area of lake Michigan varies from an average of 26 inches to an average of about 35 inches. In the section nearest the lake the precipitation is lightest, probably not averaging more than 27 to 28 inches. In this region run the Milwaukee, Sheboygan, and Manitowoc rivers.

In the section west of Green bay the annual precipitation is greater. Along the Upper Fox river it is about 30 inches, and increases toward the north. The heaviest precipitation is on the region about the Menominee and the streams north of it, where the average is not far from 35 inches per annum.

It will be noticed that the topography is such that the largest streams, draining the greatest area, are situated in the region receiving the heaviest precipitation. The character of the country must also have some influence upon the streams.

The Lower Fox drainage system contains, beside the large reservoir of lake Winnebago, several smaller lakes and extensive lowlands, which prevent rapid drainage. The northern streams run through tracts which have scarcely felt the hand of industry. No careful farming and drainage conducts the rainfall rapidly to the water-courses, but the roots and grasses, with the shade of the forest trees, act beneficially in preventing the rapid melting of snow and in holding back the water for a more gradual distribution throughout the seasons.

LOWER FOX RIVER.

The Indian name of this river was Neenah. The outlet of lake Winnebago, in eastern Wisconsin, it starts from the north end of the lake, and, flowing in a rather direct northeast course 37½ miles by water, it finally reaches the level of lake Michigan in the head of Green bay.

That which makes this stream of special importance to a report of this nature is the magnificent system of water-powers which it affords. These are building up manufacturing interests to an extent that is destined to make the Lower Fox River valley stand pre-eminent among the manufacturing centers of the West. But the interest centering in the river is not confined to that derived from its development within the last few years. Owing to its peculiar relations, both to the Mississippi and to the important waterway along the great lakes and the Saint Lawrence to the Atlantic, the Lower and Upper Fox have, as well as the Illinois river, the distinction of being one of the two routes by which the early Jesuit missionaries and explorers made their perilous canoe voyages through the unknown wilderness to the Mississippi. Through the succeeding years the example of these adventurous Frenchmen has been followed, and, later, along these two routes were established, to a certain extent, continuous water channels from the gulf of Saint Lawrence to the Mississippi.

RESOURCES OF THE REGION.

Before the time of railroads in that country the great advantages of the water route brought much traffic along the river, and thus early gave it a prominence. Since that time the productiveness of the country has made it prosperous, but especially are we to look to the splendid water-power afforded by the river for the rapid growth of the valley—a growth which is yet in its youth.

Already are the manufacturing towns of Appleton, Neenah, and Menasha looked upon as among the industrious centers of the state, and the Lower Fox river is destined to play a most important part in the further development of manufactures.

Stated succinctly, the facts are these: The crude materials are on every hand, the means of transportation are abundant and increasing, and the power for manufacturing is supplied in a prodigal manner. Let enterprise step in and make the three serve each other, and we have the conditions which have made Appleton, and which are to make the valley, one busy scene of manufacture.

NATURAL PRODUCTIONS.—Along the river and in the counties adjacent is fine wheat-producing soil, and west are the great grain-fields, with which it is connected by railroad.

Lying west in its own drainage basin, and north in Wisconsin and Michigan, are the pine forests, not yet robbed of their heavy timber, and within easy access grow the hard woods, which are suitable for the manufacture of agricultural implements and the innumerable other applications of that useful article. Great quantities of poplar for the manufacture of wood-pulp and the making of paper are at hand, and spruce and pine, which are used foı the same purpose, are easily obtained from the forests near by. The water of the river is of excellent quality for the manufacture of paper.

The railroad leads direct to the iron region along the Menominee, in the upper peninsula of Michigan. Woolen goods are manufactured, and lately it is found that the raising of flax is successful, and flax-mills are being projected.

Thus is seen what are the productions immediately surrounding the river, and, with the facilities of tranportation enjoyed, there is no reason why a large section of country should not be tributary to it.

The value of the manufactures of Appleton for the year 1880, amounting to $3,182,000, are given in a succeeding table. This place has a population of over 8,000 people, and is the most prominent town of northeastern Wisconsin.

TRANSPORTATION FACILITIES.

RAILROADS.—The means of transportation are most excellent, lying as the valley does in the neighborhood of one of the great lakes, and embraced by important railroad lines. It is a pretty good indication of the natural advantages of the valley when three large railroad companies should compete with each other in the possession of a trade which they see booming in the future, and which is well represented by the traffic of to-day. Numerous lines lead from the valley in all directions. The Chicago and Northwestern railroad runs from Chicago, along the Lower Fox river and by way of the Menominee iron range, through Michigan; the Wisconsin Central railway and branches leading to Chicago, run east of the Lower Fox to Green bay, and on the west tap the wheat regions, while a branch running north passes through the pine region and the Penokee iron range, near lake Superior; and the Milwaukee, Lake Shore and Western railroad connects Appleton with a lake port on the east, and, extending west, connects at New London with the Green Bay and Minnesota railway, which runs from the head of Green bay to the Mississippi at Winona. An extension is also in course of building by the Milwaukee, Lake Shore and Western railroad northwest through the undeveloped country in that direction. These railroads run to and along the river, and the facilities of connection with the manufacturing establishments are exceptionally fine.

WATERWAYS.—As regards water communication, the advantages of the valley are also fine. Depére is at the head of lake navigation, and forty miles east from Appleton is the lake shore, where there are also ports. There is a scheme for connecting with the Milwaukee, Lake Shore and Western railroad a line of steamers to run across the lake to Michigan and connect with railroad lines in that state. Along the valley itself is a system of navigation, which in that portion of its course is in a good working condition. It is a portion of the Fox and Wisconsin transportation route between the great lakes and the Mississippi.

In 1836 the first government survey was made of this route, and since that time there has been a more or less continual attention bestowed upon it. The system consists of a series of slack-water dams and locks, with canals around the west rapids up the Lower Fox river to lake Winnebago, then lake and slack-water navigation along the Upper Fox to Portage. There the river runs within 1½ miles of the Wisconsin river, and across the low, sandy plain intervening a canal is cut, connecting it with the latter. The navigation is then down that stream to the Mississippi.

Although the scheme would seem to be an excellent one, the route at present, regarded as a through line, is of little if any value, and is practically unused, except for local traffic. The main difficulty is with the Wisconsin, which has such a shifting, sandy bed that it is extremely difficult to train it. Much money has been expended in the effort to improve this river, and until it is done the route will be of little importance, except locally. The portion

along the Upper and Lower Fox rivers is more easily controlled, and is used locally by small boats. For example, barges have been employed in shipping granite from quarries at Montello, on the Upper Fox, to Portage, whence it is sent as paving blocks to Chicago. A large amount of wood is annually taken down the river to the blast furnaces at the lower end, and the pulp-mills keep several boats employed. Considerable lumber is carried, and the rates of freightage by water are very much less than by land. In such ways the canal is useful. The portion along the Lower Fox river from lake Winnebago down is in by far the best condition, and if all was like it the route would be of considerable importance. The navigation route has its influence on the development and control of the water-power of the Lower Fox, as will be noticed farther on in this report.

PHYSICAL DISCUSSION OF THE LOWER FOX DRAINAGE BASIN.

It will be noticed that a distinction is made between the Upper and the Lower Fox rivers. The reason for this is simply that, except in name and a certain relation to the transportation route which they bear in common, they are no more the continuation, one of the other, than the Lower Fox is a continuation of any other stream which feeds it.

System of drainage.—It will be seen on the map that the drainage system consists, with very inconsiderable exceptions, of two prominent streams, the Wolf and the Upper Fox, running into lake Winnebago, and this emptying by the Lower Fox into Green bay, an arm of lake Michigan. The Lower Fox, then, is the outlet whereby a section of the state 155 miles long and averaging 39 miles wide drains into the lake.

The peculiar form of this drainage basin will be noticed. Starting in a point about 25 miles from the northern line of Wisconsin, it gradually widens out to 60 and finally to 70 miles wide on an east and west line at the southern extremity, in latitude 43° 30′. On the eastern side of the basin is its outlet, the Lower Fox. The two rivers which collect its waters previously to depositing them in the reservoir of lake Winnebago are the Wolf river on the north and the Upper Fox on the southwest, the Wolf river being by far the larger stream, running nearly the whole length of the basin, and having a drainage area over twice as large as that of the Upper Fox.

Overflow from the Wisconsin river.—Another singular feature is, that the Wisconsin, which is at Portage 5 or 6 feet higher than the Upper Fox, actually overflows into that stream in high water, and is mainly the cause of its freshets, adding no inconsiderable amount to the flow from the basin.

Peculiarity of the Fox River valley.—Giving additional interest to the study of this drainage system is the prominent character of the Fox River valley. The depression filled by Green bay is continued southwest, forming the Lower Fox valley and the basin of lake Winnebago. There the valley appears to branch, one arm extending as the valley of the Upper Fox and the Wisconsin valley from Portage down, the other running south as the valley of the Rock river, which flows into Illinois. This valley and branches are no product of the imagination, but are strongly marked, the east and south slope being very steep, while the other slope is gradual, especially on the portion running north and south. One point specially to be noted is that the valley is continuous from the Upper Fox down the Wisconsin, only a low, sandy plain separating the two streams.

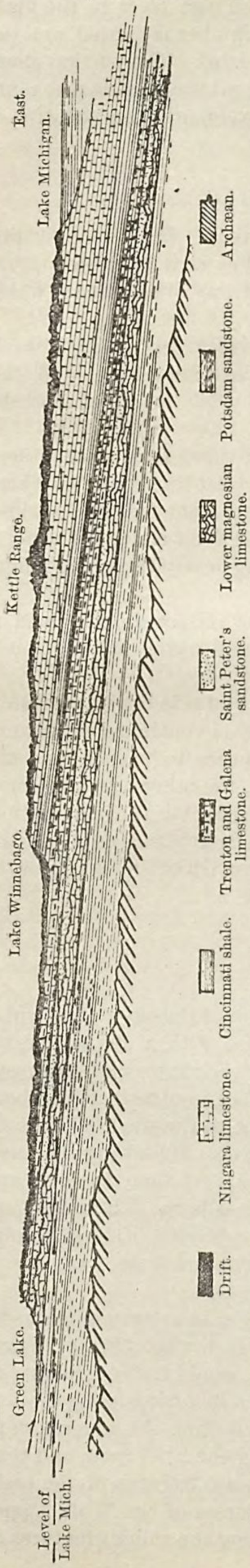
It is evident that there have been great changes in the hydrography of this region.

GEOLOGICAL HISTORY.

The geological structure, as indicated in the state geological report, is this: First, a rib of the old metamorphic rock, extending south through the center of the state, sloping east and west, and also with a slight general declination toward the south. Upon this the seas of the successive epochs deposited their rock layers, the outcrops of these successive layers forming, as would be supposed from its shape, a succession of concentric curves about their Archæan base. Beginning on the east side of the state, they run south, then curve to the west, and finally run northwest in Minnesota and Iowa. A section through this succession of strata is given. Following the slope of the old base, the different strata inclines to the east; farther south the slope is south, and then in Iowa and Minnesota southwest; and some of these strata are harder and less liable to wear than the others. Then, the hard lower magnesian limestone is underlaid by the softer Potsdam sandstone, and immediately above it is the soft Saint Peter's sandstone. The hard Trenton group of limestones is underlaid by the Saint Peter's sandstone, while above it are the soft Cincinnati shales. Lying on the Cincinnati shales is the hard Niagara limestone.

The general slope of the surface of these rocks, as was mentioned, is toward the southeast in eastern Wisconsin; hence the natural tendency of this drainage in the time preceding the glacial period was toward the southeast. What is more natural to suppose than that the earlier streams, as they cut into the rock, would halt on coming to the outcrop of the hard strata, and, eating their way through the softer underlying bed, and following along the line of outcrop of this hard rock, would cut their valleys in a south and north direction? Also, from the general slope of the strata, the tendency would be to greater erosion nearest the east bank, undermining the hard rock, and thus making the east slope of the valley precipitous. Such are believed to have been the main features of the early drainage of eastern Wisconsin, and most strikingly is this view upheld by the present courses of the Wolf, Upper Fox, and Wisconsin rivers. The glacial action has not so modified the surface as to destroy the salient features of the old preglacial topography.

ANCIENT VALLEY OF THE WOLF RIVER.—The modern Wolf river, rising in the Archæan region of northern Wisconsin, runs southeast until it strikes the stratified rock, whence it runs in such a valley as is just mentioned, following the cliffs of the hard lower magnesian limestone, with its bed in the Potsdam sandrock. At lake Poygan it turns east, owing, it is believed, to glacial action, but the old valley keeps straight on along the Upper Fox, and then bending to the west, without a change, becomes the valley of the Wisconsin river to its mouth. It is a well-ascertained fact that the upper Wisconsin, until the glacial action choked its course, drained through the Devil's lake into the Wisconsin valley at Sauk City, 20 miles below Portage, and the conclusion is inevitable that the Wolf river, and nearly all the present drainage of the Fox River system, ran southwest to the Mississippi in the preglacial time.



GEOLOGICAL SECTION ON AN EAST-AND-WEST LINE THROUGH THE SOUTHERN END OF LAKE WINNEBAGO, WISCONSIN. (From the Geological Report of Wisconsin.)

GREEN BAY AND LAKE WINNEBAGO VALLEY.—East of the old valley just described is the Green bay and lake Winnebago valley, of similar characteristics, and the more prominent of the two, but in the preglacial times it could hardly have had its present dimensions. The valley was probably started by the erosion of streams, but was dug out to its present size by the glacier. The western slope is gradual; but the eastern slope is precipitous, being cut out of the soft Cincinnati shales, overlaid by the hard Niagara limestone.

The bed is the hard Galena limestone of the Trenton group. The eastern side of the valley, which forms the eastern limit of the Lower Fox drainage basin, rises abruptly 100 to 200 feet above the water in Green bay, and continues a line of cliffs along the east shore of the present lake Winnebago, and then south, although largely covered up with drift in the southern part of the state. The geological section given previously, from lake Michigan west through Fond du Lac, shows both of the old valleys.

GLACIAL ACTION.—Succeeding this preglacial condition came the glacier, sending an immense sheet down to cut out the valley of lake Michigan, and a tongue up the Green Bay valley, gouging this out to its present size. On the peninsula between Green bay and lake Michigan was formed the prominent Kettle range, a medial moraine. The glacier tongue extended down the Rock River valley, and on the west spread out over the Fox River basin well toward the Wisconsin river.

The floor of the Green Bay valley has a rapid rise, so that at lake Winnebago it is about 170 feet above Green bay. The portion of the old valley now occupied by the Upper Fox was largely filled up with drift, and it seems probable, from the geological reports, that to the action of the glacier in cutting down the intervening lower magnesian rampart and in filling up to a certain extent the Upper Fox valley is due the change in flow of the Upper Fox and Wolf rivers through the newly-enlarged Green Bay valley to the lake. It is also likely that the change in flow is partly due to the depression toward the north, which occurred during or after the recession of the glacier.

EXPANSION OF LAKE MICHIGAN.—This depression caused a large body of water, which was nothing more than the expansion of lake Michigan. The probable shore-line of this ancient lake is shown by the dotted lines on the map. The outline is taken from the state geological report. The lake, in advancing upon the drift left by the glacier, carried off the finer particles, depositing them in deep water, and forming a beach-line of sand and gravel, the finer deposit receiving the name of lower red clay. During a second advance of the lake a similar process was gone through with, and the upper red clay deposited. There were subsequent modifications of these. The red clay forms to a large extent the soil of the Fox River valley, and is of fine quality, and the ancient shores of the expanded lake are traced by this deposit. The lower red clay ascends the Lower Fox valley to a few miles north of Fond du Lac. On the west it extends up the Upper Fox to above Berlin, and along the Wolf river to beyond Shawano. It seems probable that the deposit referred to by some as the deposit from a former great enlargement of lake Winnebago is really the deposit from the waters of lake Michigan when it occupied this area, as the shore-line laid down for the old boundary of the lake corresponds very closely with the so-called old shore-line of lake Winnebago.

ORIGIN OF LAKE WINNEBAGO.—Lake Winnebago is due, according to Professor Chamberlain, to a slight drift barrier thrown across the valley. The old channel is at the eastern corner of the lake, and is filled with drift. The rock bottom is lower than the limestone terrace over which the present outlet passes, and, if once opened, it would drain the lake.

SUMMARY.—Thus we draw the conclusion that in preglacial times the greater part of the present Fox River basin drained into the Mississippi; that during the recession of the glacier the flow changed to its present direction; that following or accompanying the recession of the glacier was an advance of lake Michigan, rearranging the drift and depositing the red clays; and that lake Winnebago is a comparatively modern reservoir, formed in the valley by the drift deposition of the glacier.

The history of the region, its manufacturing and commercial facilities, and physical geology have been described. It now remains to give a general idea of the water-power, and its special advantages, before describing in detail particular localities.

LEGAL CONDITIONS OF THE WATER-POWER.

LEGAL HISTORY OF THE WATER-POWER.—As the present ownership of the power depends in a large degree upon past legislation in relation to the navigation route, a brief account of the changes this has gone through will be necessary. The dates and early history are obtained from the annual review of the Appleton *Post*.

In 1846 Congress passed an act granting a large amount of land to the state of Wisconsin, soon to be admitted, for the purpose of making a navigable route from lake Michigan along the Fox rivers to the Wisconsin, and in 1848 the legislature of the new state just admitted accepted this grant. In 1853 the state, after expending $400,000 upon the improvement, passed the whole matter, including the land, over into the hands of a company called the Fox and Wisconsin Improvement Company. This company sold some of the land, and issued bonds to the amount of $500,000. With this they commenced active work, and in June, 1856, the first steamer passed through from the Mississippi river to Green bay. On the advent of railroads the route fell into disuse, and the company being unable to pay expenses and interest, the holders of the bonds brought suit against it. The result was the sale in Appleton of the franchises, property, and land-grants of the company, the purchasers organizing in 1866 as the Green Bay and Mississippi Canal Company. In 1870 the United States appraised the value of the locks and canals at $145,000, and, paying the company that amount, took possession of them. Since that time the government has had control of the navigation route. The Green Bay and Mississippi Canal Company did not dissolve, but still retained its land-grants, water-power franchises, and other property.

In this condition the company exists at the present day, and, as may be imagined, are very influential owners along the river. They claim the right to all surplus water after the wants of navigation are fulfilled, and, therefore, the right to tap the canals at any point and draw off the water, provided they do not interfere with navigation, as also the right to take all the surplus flow of the stream at the head of each set of rapids and use it at that level. They do not claim ownership of power which is improved at a level below the head of a rapids by persons owning the land and using water which has passed the tail-races of the company. They own, by the original grant and subsequent purchase, a large number of valuable sites at the several powers along the river; but there are cases where, while the Green Bay and Mississippi Canal Company own the power, others own the land. In one case the arrangement has been made of forming a water-power company consisting of the owners of the property and the individuals forming the Green Bay and Mississippi Canal Company, thus combining their interests; in another case a company has been at work improving a power to come from the upper level of a rapids. They own the land, but the Green Bay and Mississippi Canal Company claim that they have no right to the power, and as soon as they begin using it intend, it is said, to bring suit to compel them to pay rent.

CLASSIFICATION OF THE POWERS.—There are, then, with the exception of some powers in use which have their rights from long-established usage, four different classes of powers from a legal point of view. Some of these powers are developed and in use, some in process of development, and others are not yet touched. They are:

1. Powers from the first levels of rapids, where the Green Bay and Mississippi Canal Company control both the power and the land.

2. Powers from the first level of rapids, where the Green Bay and Mississippi Canal Company, as individuals, go into partnership with the owners of the surrounding land, forming an hydraulic company.

3. Powers from the first level of the rapids, where persons owning the land intend to utilize the power, and the Green Bay and Mississippi Canal Company intend to bring suit to make them pay rent for such use.

4. Powers below the first level of the rapids, where persons owning the land have improved or may improve the power without molestation from the Green Bay and Mississippi Canal Company.

Of the above classes of powers it seems probable that the third will either have to pay rent or form some such arrangement as in the second class. The first, second, and fourth classes are on a substantial basis.

RATES OF LEASE.—The improved powers are standing, in most cases, waiting to be utilized, and offering the most advantageous terms to manufacturers. Much is already taken up, especially on the upper portion of the river, but even there there is a large amount of unutilized power. There are also opportunities for companies to form, as has already been done in several cases, for the purpose of improving water-power sites and leasing the power, and the rates of lease, which have been extremely small, are being increased as the demand increases.

Prices are about the same all along the river. In the winter of 1880–'81 the rates at Appleton were these:

For a large water-power of from 500 to 1,000 horse-power, with the necessary land, and a short lease of 10 or 15 years, the rates were even as low as $1 to $2 per horse-power per year.

A power of from 100 to 300 horse-power would bring $3 to $4 per horse-power per year.

A 50 horse-power site of one-half acre would lease for from $2 to $3 per horse-power per year.

At Kaukauna a 100 to 300 horse-power site will bring $2 to $5 per horse-power per year. Power has been recently leased there for a wood-pulp mill of 300 horse-power at the rate of $5 per horse-power.

There is a probability that the scale of prices will increase, so that an ordinary lease will bring as much as $5 per horse-power per year. Even this is very small compared with the eastern rates.

GREEN BAY AND MISSISSIPPI CANAL COMPANY.—The Green Bay and Mississippi Canal Company formerly consisted largely of eastern capitalists, who already had large investments, and did not take special interest in the development of the water-powers along the Lower Fox. Lately, however, the company was reorganized, putting the control into the hands of persons interested in the development of that region. Their policy is said to be to make a rapid and general improvement of their powers along the river, to give manufacturers the option of buying or leasing, and to offer very favorable terms. The president is John Van Nortwick; vice-president, H. J. Rogers; secretary and treasurer, A. Ledyard Smith, of Appleton.

There are several other companies and individual owners, of whom subsequent mention will be made in the detailed descriptions.

CHARACTERISTIC FEATURES OF THE RIVER AS A WATER-POWER STREAM.

PAST AND PRESENT.—When the Lower Fox flowed untrammeled through the wilderness, its course of 37½ miles was bounded by wooded clay bluffs, from ten to seventy feet or more in height, in some places rising abruptly from the river's edge on each side, in others receding so as to leave a narrow meadow along the river bank. Through this channel ran the clear, dashing river over its limestone bed, from 300 to 1,000 feet wide, now flowing placidly along, then dashing into foam over some sudden rapid in its descent of 165 feet to Green bay. The principal rapids were at Grand Kaukauna and Grand Chute, the site of Appleton; but there were several other rapids, as at Cedars and Little Chute, difficult even for the light canoe of the Indian to pass. Now things are different, although in places the forest still droops to the water's edge. The interests of navigation have bridled the river, and a series of dams has changed it into long stretches of slack water, with perhaps a short rapid at the foot of the dam, except at Grand Kaukauna and Appleton, where the rapids are passed by canals extending from the head to the foot, while the river flows on over its steep bed.

GOVERNMENT DAMS.—The government dams are important to this report, as at them, chiefly, is situated the water-power of the river. The following table gives the location of the dams and distances of these places from the mouth of the river and from each other; also the elevations overcome in passing from the crest of one dam to that of the one above. The table was obtained from the United States engineers' office at Milwaukee, under Colonel D. C. Houston, major of engineers:

Locality.	Intermediate distance.	Distance from mouth of river.	Elevations overcome.
	Miles.	*Miles.*	*Feet.*
Green bay (mouth of river)	0.00	0.00	.....
Depère (old) dam	7.00	7.00	*5.411
Little Kaukauna dam	6.00	13.00	7.795
Rapid Croche dam	6.00	19.00	9.221
Grand Kaukauna dam	4.50	23.50	50.121
Little Chute dam	2.50	26.00	36.158
Cedars dam	0.75	26.75	9.800
Appleton, lower dam	3.00	29.75	.....
Appleton, upper dam	0.75	30.50	36.265
Menasha dam	5.00	35.50	10.424
Lake Winnebago (source of river)	2.00	37.50	.....

* The rise immediately at the dam.

Beside the dams given in the table, there is one at Appleton, between the upper and lower dams, used simply for power, and independent of the government. The map shows that there are two channels from the lake, uniting about one and a half miles below to form the main river, called the Neenah and Menasha channels, from the towns at their respective ends. The government has a dam at the foot of each channel, controlling the level of the lake. The fall is about the same with both. The navigation locks are at the dam on the east or Menasha channel.

FLOW OF THE RIVER AND THE WATER-POWER.—The minimum flow of the Lower Fox river is given in General Warren's report as 2,320 cubic feet per second. The ordinary low-water flow is taken at 2,500 cubic feet per second, or 150,000 cubic feet per minute. This will give, with 10 feet head, 2,836.35 theoretical horse-power, or, with an efficiency of 75 per cent., an available power of 2,127.26 horse-power.

The tributaries of the river below lake Winnebago are small brooks of no consequence, and it can fairly be assumed that they hardly more than balance the effects of evaporation; hence the total theoretical power of the river, in an ordinary low stage, in its descent of 165 feet from lake to bay, is pretty closely 46,640 horse-power.

The following table gives the localities of the available powers, the total available head of water in feet, and the resulting horse-power at an ordinary low-water stage of 2,500 cubic feet per second:

Place.	Available head, in feet.	Theoretical horse-power.	Effective horse-power, at 75 per cent.
Neenah and Menasha	8.5	2,411	1,808
Appleton, upper dam	16.0	4,538	3,404
Appleton, middle dam	10.0	2,836	2,127
Appleton, lower dam	10.0	2,836	2,127
Cedars	9.0	2,553	1,915
Little Chute	34.0	9,644	7,233
Grand Kaukauna	50.0	14,182	10,636
Rapid Croche	8.0	2,269	1,702
Little Kaukauna	7.5	2,127	1,595
Depère	6.0	1,702	1,276
Totals	159.0	45,098	33,823

It is rare to find a stream in which such a complete utilization of the power is possible.

UNIFORMITY OF FLOW.—Foremost among the characteristics of the Lower Fox river is its steadiness. At Appleton the ordinary variation from low to high water is scarcely more than two feet throughout the year, and a three-foot rise is a very large one for this river. Lake Winnebago, like a great storehouse, regulates the supply. In a dry summer, when other streams may dwindle to brooks, the Lower Fox still fills its banks, and when winter scarcely lets the prairie stream leak between its icy fingers, lake Winnebago pours a generous flood down the valley of the Lower Fox. Nor does lake Winnebago deserve all the credit; the smaller lakes and swamps on the Upper Fox and Wolf rivers have also some effect.

It is the storage capacity of the basin that gives to the Lower Fox a special value as a water-power stream.

LAKE WINNEBAGO.—Lake Winnebago, whose major axis lies nearly north and south, is 28¼ miles long, and its maximum width is 11 miles, its minimum width, except at the extreme end, 3¾ miles, and its average width 7 miles. The area is 199 square miles, and the deepest places are about 25 feet.

Accompanying General Warren's report is a plotting of gauge readings on lake Winnebago for 1867, 1868, and 1869. These show the slowness of the changes in elevation to which it is subject. As the curve for 1868 corresponds closely to the mean where that is given, it will represent near enough the usual changes to which the lake is subject. The level was lowest in January and February, keeping nearly constant. From March 1 up to April 15 it rose pretty uniformly, reaching its highest point for the year on the 15th of April, when it was 2¾ feet above the lowest stage for the year. From April 15 to August 15 the fall was very uniform, with the exception of an undulation of about six inches in the latter part of June, due to the June rains. From August 15, through September and October, the surface was nearly constant at a low stage, but in November it rose about one foot, and in the latter part of December began slightly to fall. In 1869, owing to a wet summer, the level was high through the season.

STORAGE CAPACITY.—Whether these changes are largely caused by drawing off the water from the dams at the foot of the lake or not, the record is important as giving an indication of the times and duration of low water. The longest stage of low water is from the end of July through to the fall rains. If this can be provided for by storage, the rest of the season will be, as the fall rains fill up for the winter months. What is the present storage capacity? General Warren states that "the water-powers occasionally draw down the level of the lake nearly 2½ feet below the ordinary level maintained by the dam". It is fair to assume from the gauge plottings that, except in very extraordinary seasons, like the summer of 1867, the lake level will not fall below the crest of the dam during the summer, except in August, September, and October, a stretch of ninety days. Supposing that the extent to which it is feasible to draw down the level is 2 feet, instead of 2½ feet, leaving the extra 6 inches to counterbalance the error in calculations due to the slope of the bed at the shores, the volume ready to be drawn off when the level is up to the crest of the dam is 11,493,603,200 cubic feet.

The officers of the lake survey estimated in 1861–'67 that the evaporation on the lakes for the three months mentioned, August, September, and October, amounted to eleven inches in depth. Assuming this to be true for lake Winnebago, there is a storage left available of 6,225,701,733 cubic feet, which for ninety days would give a discharge of 800 cubic feet per second to supplement the natural low-water flow.

Colonel D. C. Houston, in charge of this district, kindly furnishes the information that on August 9, 1878, when the water was low, the discharge of the Wolf river was 1,608 cubic feet per second, and of the Upper Fox 1,043 cubic feet per second, giving a total of 2,651 cubic feet per second. Supposing that the extreme low-water flow into the lake was as low as 2,000 cubic feet per second, this, and the regulated flow from storage, would give on a low estimate an available discharge of 2,800 cubic feet per second through the low-water months mentioned, more than sufficient to keep up the ordinary low-water flow on which the calculations of the available water-powers of the Lower Fox are based.

The lake level would lower at the rate of about one-quarter to one-third of an inch per day if regulated as described, of which about one-half would be due to evaporation.

It must not be forgotten that the land about the lower part of the Wolf river is swampy and the fall slight. The high water in the lake, which sometimes reaches three feet above the ordinary level held by the dams at the outlet, floods away back, filling the swamps and lakes before mentioned, and really extending the limits of lake Winnebago to a large extent. This backwater takes a good while to run out, and exerts a considerable effect in steadying the flow.

FRESHETS FROM THE WOLF AND UPPER FOX RIVERS.—But the Wolf and Upper Fox, while they aid lake Winnebago in this way, are also the means of producing the freshets on the Lower Fox, although a three-foot rise is hardly worthy of the name. A few years back there was an extraordinary rise in the Wolf, filling its flats to the width of several miles and raising the Lower Fox unusually high. The rather singular state of affairs exists in this basin of a foreign stream intruding its surplus waters.

It has been stated in another place that the Wisconsin and the Upper Fox, at Portage city, flow through the same sandy plain, without any definite water-shed between them. The Wisconsin is 5 or 6 feet higher than the Upper Fox, and in a high stage discharges a considerable volume, largely through the channel of Neenah creek, into the Upper Fox. In the spring of 1881 there was a heavy freshet on the Upper Fox from this cause chiefly, and it had its effect upon the lake level.

SPRINGS IN LAKE WINNEBAGO.—The opinion is expressed by some that there are extensive springs in the bed of lake Winnebago, feeding it. Captain N. M. Edwards, an engineer at Appleton, for many years connected with the river, dissents from this view, and says that there is just as likely to be as much leakage as supply through the bed, which seems probable.

From the geological section previously given, it will be seen that the rock strata slope to the east from lake Winnebago to lake Michigan, 165 feet below it, and also that the stratum immediately below the lake is the Trenton limestone, over which are the drift and red clay, forming the bed of the lake. The Trenton limestone is described by Professor Chamberlain as having permeable water-bearing strata, and it is quite possible that the water, under the hydrostatic pressure of the lake, should find porous portions of its drift bed, and so, by means of the limestone strata, sink down to lake Michigan.

ARTIFICIAL RESERVOIRS.—Although the Lower Fox is so unchangeable, still, to see it rushing past Appleton when in a high stage, one would think it a wasted torrent, and it is true that an enormous volume of water passes down the river unused in high water. There is, with the present improvements, all the water needed in an ordinary low stage, but there are many more available sites at the different powers along the stream than could be supplied at ordinary low water. Mills using a small power, say 50 horse-power, could in most places utilize the space available without exhausting the capacity of the river; or even factories using a large power, but requiring much room, would not concentrate the power to the detriment of the full development of the locality. Manufactories, however, using from 500 to 1,000 horse-power in a small space, as for example, wood-pulp mills, would exhaust the power without using the available space. This is not of much account except to the owners of the land, as the power is of as much value intrinsically when concentrated as when scattered in small industries, but it serves to show that there is a limit to the amount of power which may be reached before the limit of available mill-sites is reached.

In the future, and the near future too, it may become a matter of importance to hold back the great surplus which wastes itself in a few weeks, and, dealing it out gradually, to make the freshets still less, to bring the river nearer to the average flow for the year. As the land about the Wolf river is cleared and drained, making the stream more flashy, this question will increase in importance. Where is the remedy? It is impracticable to raise the water of the lake to a higher level than is now done because of the lowlands to the west and south. As it is now, complaints are heard of overflows on the farming land along the shores.

Along the upper portion of the Wolf are many lakes and marshes, and although, so far as can be learned, no surveys have been made for this purpose, still it is thought by those interested in the subject that good sites could be found for storage reservoirs to hold back the floods until required. The land there is wild, not bringing more than $2 to $3 per acre, and could be cheaply bought for flowage. It is true that the basin narrows to a point at the upper portion of the river, but enough water could be collected to have an important effect on the Lower Fox. The development of the water-power in the future will probably justify the outlay.

The wind exerts a slight effect upon the waters of lake Winnebago, a strong wind from the north and east lowering the level slightly at the outlet. The crest of the Menasha dam is higher than that of the Neenah dam, and on the latter flash-boards 18 inches high are used when the high water is over, maintaining the level above the crest of the dam for a much longer time than would be the case otherwise. These sometimes lessen the flow farther down stream for the time.

FLUCTUATION DUE TO THE MILLS.—There is an element of unsteadiness in the Lower Fox itself, due to the improvements upon it. On Sundays the mills at the head of the stream are shut down, and all the water that passes down the river goes over the crest of the Neenah dam. The result is that, except in high water, the river

lowers nearly a foot at Appleton, and does not recover its stage until well on into Monday. At Depère, the lowest power, they feel the effects of this all day Monday.

FEATURES FAVORABLE TO WATER-POWER.—The river is not troubled with ice-gorges and damage from floating ice, because the ice on lake Winnebago quietly melts without gorging the river. There is difficulty after very cold nights from anchor-ice forming on the rapids, and some of the mills have their racks choked with it in exceptionally cold weather; but the system of slackwater navigation used in part on the river makes the difficulty less than it would otherwise be.

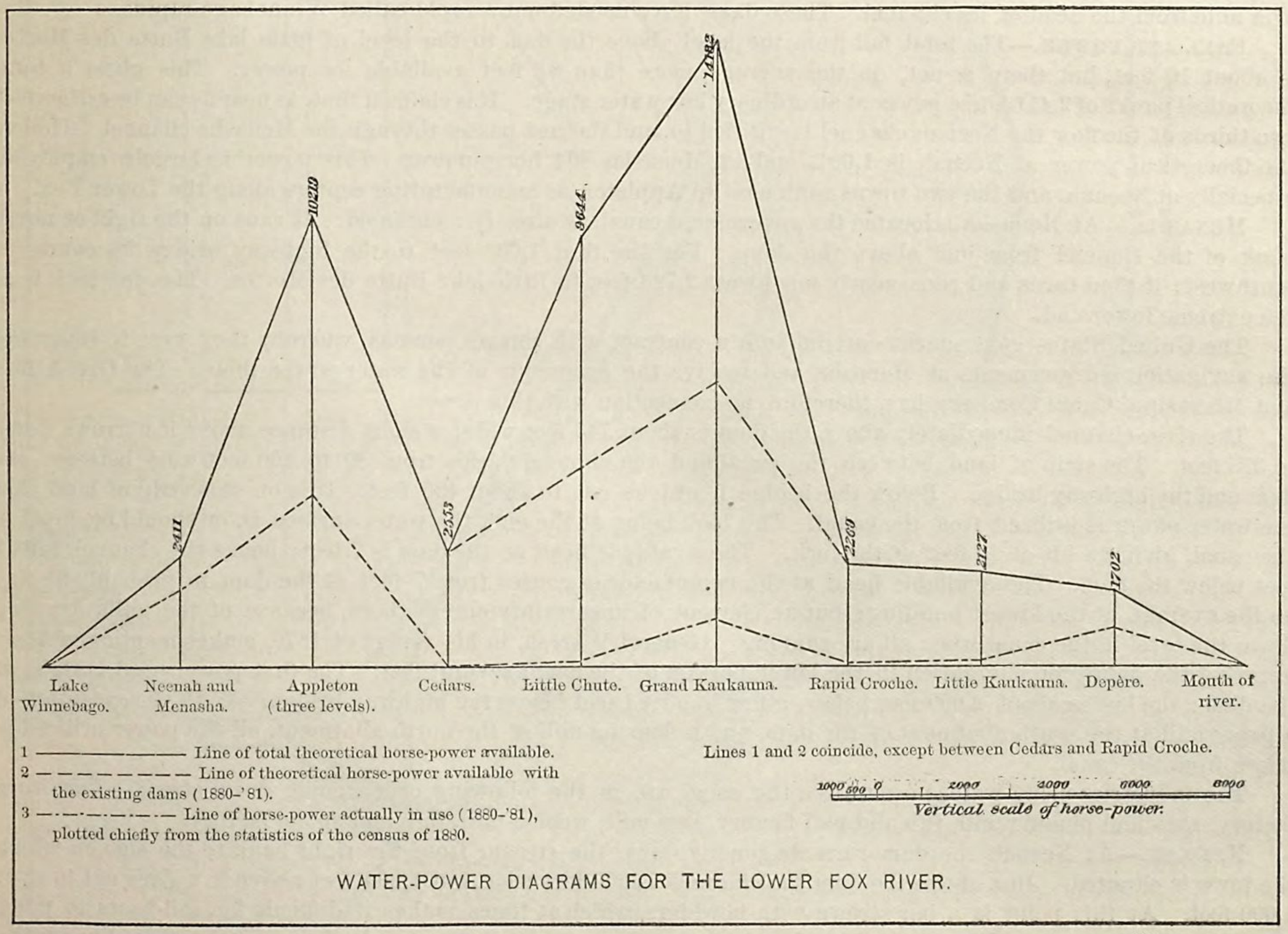
Because the stream is so uniform in its flow the mills are not stopped from backwater, as is the case with so many water-powers. Another advantage from the steadiness of the river, and perhaps one of the most important ones, is the facility for railroading right in the channel of the river, running side-tracks wherever needed to the different manufactories. At Appleton especially is this marked, because the power is there most developed. Tracks run hither and thither on a short trestle or crib work, only a few feet above the water, with no danger from freshets, and no fear of ice-gorges.

Again, because the freshets rise so little above the ordinary stage of the river, mills can be built out into the stream with perfect safety, and in some places, where the bluffs scarcely leave room for the canal, this is very advantageous.

The bed is a hard limestone at nearly all of the powers, which makes an excellent foundation. It is a good building-stone, bluish-gray, and compact in the best samples. The government has opened excellent quarries at Grand Kaukauna and on Duck creek for supplying the erection of the fine cut-stone locks on the canal, and in the work of improving the powers this stone is removed from the bed and used right at hand for the building of dams, retaining walls, etc.

DESCRIPTION OF THE WATER-POWERS ALONG THE LOWER FOX.

A table has been already given of the water-power localities, the distances apart, and the total fall between them. From the source down they are: 1. Neenah and Menasha; 2. Appleton (upper, middle, and lower levels); 3. Cedars; 4. Little Chute; 5. Grand Kaukauna; 6. Rapid Croche; 7. Little Kaukauna; 8. Depère.



WATER-POWER DIAGRAMS FOR THE LOWER FOX RIVER.

The general features have been already considered, and we will now discuss each one of the above-mentioned places separately.

The accompanying maps were thus prepared. The outlines were traced from the maps of the Green Bay and Mississippi Canal Company chiefly and partly from the maps in the possession of the United States engineers in charge of the river. The different manufactories are sketched in, chiefly from rough plans made by me in the field, but those at Menasha, Little Chute, and Grand Kaukauna were entirely located by Captain N. M. Edwards, of Appleton. It will be readily understood that the buildings are not drawn to scale, and that their location is approximate, although it is believed to be not far out of the way.

The figures 10, 15, etc., in the channel represent the average available head of water opposite those points and start with the level of the water in the pond as a datum plain.

Descriptions of the dams on the river and drawings of them are given in a separate section further on.

NEENAH AND MENASHA.

The Lower Fox starts in two channels from the northern end of lake Winnebago. These channels, which are nearly parallel, are about three-fourths of a mile apart, and flow almost west, the northern one for 2 miles, the southern for 1¼ miles, and then empty into little lake Butte des Mortes. This lake is 3¼ miles long by about half a mile wide, and is merely an expansion of the river, running north, at right angles to the direction of the two channels. At its northern end it narrows down to 1,000 feet, the width of the river there. At the lower ends of the two channels above mentioned are two towns: Menasha, on the northern side of the northern channel, and Neenah, on the southern side of the southern channel. These towns give their names to the respective channels. The population of the first in 1880 was 3,140, and of the second 4,203. The two towns are about one mile apart, and there is constant communication over the low island intervening.

The banks of the river here are quite low, being only about 10 feet above the water, and above the dams there is some slight overflow at times. These dams, situated one on each channel, act in concert to preserve the level of lake Winnebago. The navigation is now along the Menasha, or northern channel. The Menasha dam is situated a little less than 1¼ miles by water from the head of this channel. The Neenah dam is slightly over three-fourths of a mile from the head of its channel. These dams have flooded out a rapid called Winnebago rapids.

FALL AND POWER.—The total fall from the level above the dam to the level of little lake Butte des Mortes is about 10 feet, but there is not, on the average, more than 8½ feet available for power. This gives a total theoretical power of 2,411 horse-power at an ordinary low-water stage. It is claimed that, as near as can be estimated, two-thirds of the flow the Neenah channel is entitled to, and the rest passes through the Menasha channel. Hence, the theoretical power at Neenah is 1,607, and at Menasha 804 horse-power. This power is largely employed, especially at Neenah, and the two towns rank next to Appleton as manufacturing centers along the Lower Fox.

MENASHA.—At Menasha is located the government canal, as already mentioned. It runs on the right or north bank of the channel from just above the dam. For the first 1,600 feet to the highway bridge its course is southwest; it then turns and runs nearly northwest 2,720 feet to little lake Butte des Mortes. The one lock is at the extreme lower end.

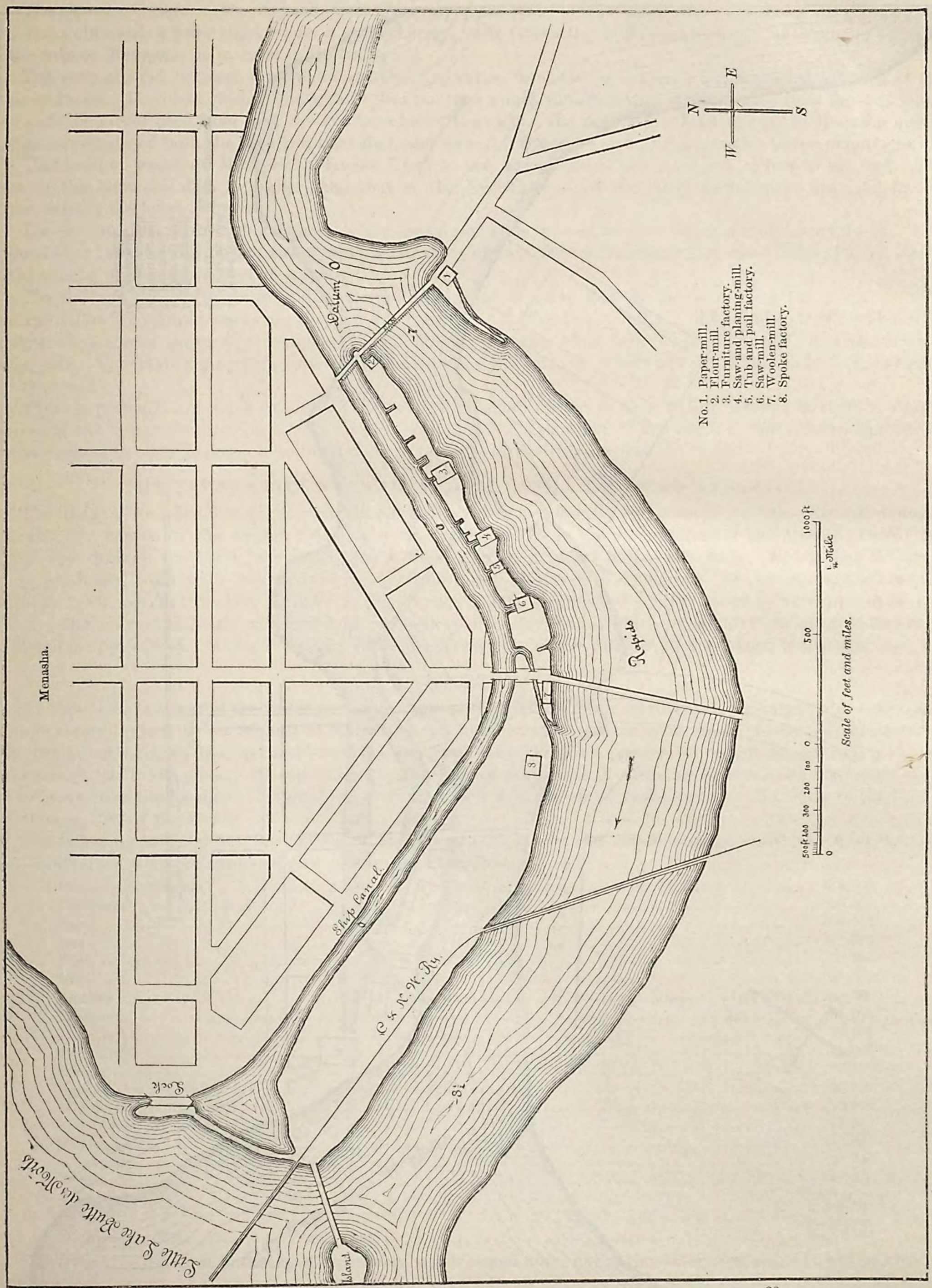
The United States government entered into a contract with certain persons, whereby they were to construct the navigation improvements at Menasha and receive the ownership of the water-power there. The Green Bay and Mississippi Canal Company has, therefore, no connection with this power.

The river channel immediately above the dam is about 745 feet wide; a short distance above it narrows down to 375 feet. The strip of land between the canal and the channel varies from 80 to 160 feet wide between the dam and the highway bridge. Below the bridge it widens out to about 425 feet. It is on this strip of land that the water-power is utilized from the canal. The lock being at the end, the water-surface is, or should be, level in the canal, giving a lift of 10 feet at the lock. The available head at the dam is 7 feet; hence the channel falls 3 feet below the dam. The available head at the manufactories varies from 7 feet at the dam to probably 8½ feet on the average at the lowest building; but an element of uncertainty enters there, because of the mills drawing down the level in the canal when all are running. General Warren, in his report of 1876, makes mention of their lowering the depth for navigation in the lower portion of the canal several feet. The first power used is right at the dam; the last is about 2,000 feet below, a few hundred feet below the highway bridge. With the exception of a paper-mill at the south abutment of the dam, and a flouring-mill at the north abutment, all the power utilized is taken from the canal.

The industries using water-power from the canal are in the following order, going down stream: Furniture factory, saw- and planing-mill, tub and pail factory, saw-mill, woolen-mill, hub and spoke factory.

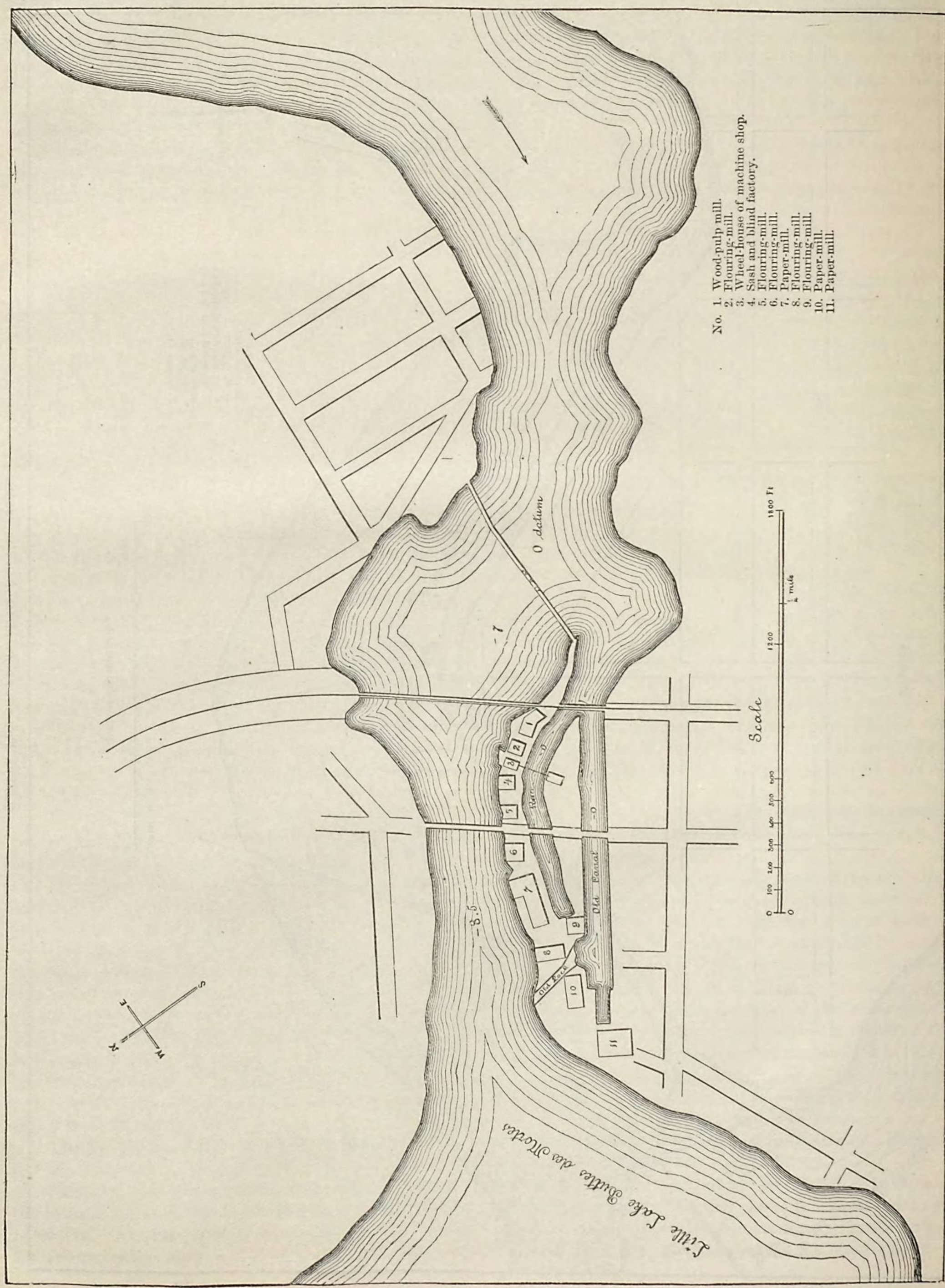
NEENAH.—At Neenah the dam runs diagonally down the stream from the right bank to the side on which the town is situated. Just above the dam the channel is 600 feet wide, but 1,200 feet above it widens out to over 1,000 feet. At this point is a bar strewn with bowlders, which at times makes it difficult for sail-boats to pass. As shown by the map, a dike of earth and stone runs down stream a few hundred feet to the shore-line on the

Neenah side. Where the dam and dike join the shore recedes, and from the bay thus formed two races start: the one nearest to the shore following its bend, and stopping after having run down stream 1,000 feet; the other keeping a



LOWER FOX RIVER AT MENASHA, WISCONSIN.

straight course across the bend for 1,350 feet, until it again strikes the river bank. This canal was formerly used by the government for navigation before the move was made to the Menasha channel. The position of the old



LOWER FOX RIVER AT NEENAH, WISCONSIN.

lock is shown in the map. For distinction, the first race is called the race, and the second the canal, and it is from these two that all the water-power used at Neenah is taken.

The riparian owners on the Neenah channel improved the water-power before the ship-canal was commenced, and thus obtained a prior right under a state charter. The Green Bay and Mississippi Canal Company have, as in the case of Menasha, no interest in this power.

The strip of land between the stream and the race varies from 100 to 150 feet wide, and on it are most of the manufactories. It will be readily understood that the race would interfere with the tail-races from the canal, and hence all the power used from that is taken from below the race. The main street leading over to Menasha nearly bisects the length of both the race and the canal, and from it drive-ways lead at right angles to the manufactories.

The head of water at Menasha averages 7 feet at the upper end of the race and 8½ feet at the foot. The crest of the Menasha dam is higher than that of the Neenah, and on the latter flash-boards are used in low water, raising the level 18 inches.

The manufacturers are rather averse to the leasing of more power, as they feel it would lessen theirs. It is claimed that the river below has risen into the tail-races of the lower mills some 2 feet above its old level, owing to the raising of the upper level at Appleton.

The Chicago and Northwestern railroad crosses the river on a line with the heads of these two races.

The following manufactories are situated upon the race: 1. Wood-pulp mill; 2. Flour-mill; 3. Wheel-house of machine-shop across the race (wire-rope transmission); 4. Sash and blind factory; 5. Flour-mill; 6. Flour-mill; 7. Paper-mill. The following manufactories are situated upon the canal: 1. Flour-mill; 2. Flour-mill; 3. Paper-mill; 4. Paper-mill.

There is probably not much available power unutilized there, except in high water. However, there is a large portion of the year when there is a large surplus wasted. The formation of the bank at the eastern end of the dam is such as to make it possible to build a race there and utilize this surplus.

THE RIVER FROM NEENAH AND MENASHA DOWN TO APPLETON.

The distance from the foot of the Menasha channel to the upper dam at Appleton is 5 miles. All this distance is slackwater, caused by the Appleton dam, and the navigation is in the stream itself. The first 2¼ miles of the course are through the little lake Butte des Mortes, averaging about half a mile wide. Below that the river bends gradually, so that the course is in a general northeast direction to Appleton. At the foot of the lake the width is 1,000 feet, but it then narrows to an average of 600 to 700, and is only 400 feet wide in one or two places. The channel is gently widening between well-wooded clay banks, which rise to a height of 50 or 60 feet as Appleton is approached. Along little lake Butte des Mortes the shores are low, and in places is marshy.

APPLETON.

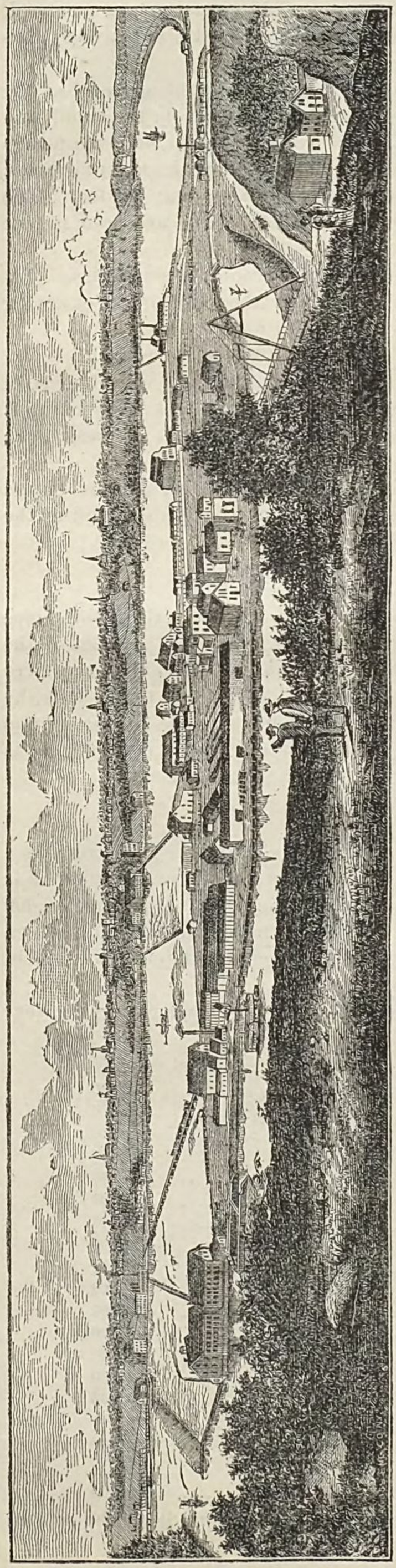
At this place is situated the water-power which has attracted so much attention to the Lower Fox valley as a manufacturing region, not on account of its having the best series of powers upon the river—Grand Kaukauna is fully the equal of it in that respect—but because it is here that the greatest development, exceeding 10,000 horse-power, has taken place. Its capabilities are by no means exhausted. Having so much the advantage of an earlier start than the localities farther down stream, it bids fair, for many years, to assert its claim to the title of the "Queen City of the Fox".

The following table, giving the amount of business transacted by the manufacturers of Appleton for the year 1880, is obtained from the annual review of the Appleton *Post:*

Farming implements	$70,000
Furniture	75,000
Flour	890,000
Gas	12,000
Hubs and spokes	86,000
Iron	355,000
Lumber	80,000
Leather	85,000
Lime, brick, etc	30,000
Machinery	38,000
Pumps	8,500
Paper (print and wrapping)	850,000
Staves and heading	110,000
Sash, doors, and blinds	75,000
Woolen goods	200,000
Wood pulp	140,000
Others	78,000
Total	3,182,500
Total for 1879	2,458,000

Nearly all the different branches of manufacture mentioned make use of the water-power, and it will be noticed that the manufactures of flour and of paper are the largest items.

FREIGHTING FACILITIES OF APPLETON.—These are unusually good. Entering the city are the Chicago and Northwestern, the Milwaukee and Northern, controlled by the Wisconsin Central, and the Milwaukee, Lake Shore and Western railroads. In addition to these is the water communication, and there is an outlet and an inlet in all directions, north, south, east, and west, easy access to the lake ports, and a healthy competition, which will suffice to keep freight rates within reasonable bounds. The Chicago and Northwestern passes through the main town, but has a long side-track running along the river the whole length of the city, connecting with the main line at each end. The Milwaukee and Northern and the Milwaukee, Lake Shore and Western roads run up the river past the city, and have their depots near the water-power. A glance at the maps will show how the tracks pass here and there over the stream, giving the greatest facilities to the different manufactories.



VIEW OF THE LOWER FOX RIVER AT APPLETON, WISCONSIN, FROM THE BLUFF ON THE SOUTH BANK, GRAND CHUTE ISLAND IN THE FOREGROUND.

42

From the upper level at Appleton to the foot of the lower lock the total fall has been stated to be nearly 36.3 feet, of which, on the average, 36 feet is available for water-power. This descent is made in a distance of 1½ miles by river. Before reaching Appleton the river has been flowing nearly northeast; but at Appleton it takes a gradual bend to the southeast, and then, just above the lower dam, a more sudden one to the northeast again. These we may call the upper bend and the lower bend. On the north or left-hand bank the clay bluffs rise steep, 50 to 70 feet high, to the rather level surface back from the river, and on this the city is situated, overlooking the upper bend. Opposite the city, on the south side of the river, is a segment-shaped flat, 3,500 feet long and 1,200 to 1,500 feet wide for a considerable distance, elevated only a few feet above the river. Formerly a channel ran through this, called south channel, and the portion of the flat north of this channel is known as Grand Chute island. Back of this rise the bluffs, as on the north shore, and the river evidently washed the foot of these bluffs at some early time.

NAVIGATION CHANNEL.—For navigation purposes the descent has been divided into two levels, the upper level and the lower level, by a government dam at the upper and lower ends of the descent, respectively. Between these two is the middle level, formed by a private dam, used entirely for water-power, and having no connection with the government.

The navigation is by the government canal from the upper level, just above the south end of the upper dam, skirting the bluffs on the south shore of the river to the slack water of the lower level. This canal is 3,600 feet long, averaging 100 feet wide, and there are three locks, with at least 6 feet of navigable depth. From the foot of this canal the navigation is by the slack water of the lower level for 1,800 feet, and then by a short canal of 1,000 feet length, with one lock, from the eastern end of the lower dam to the slack water of the Cedars dam below.

It is apparent that the water-power is divided into three levels, and each will be considered in its turn.

UPPER LEVEL AT APPLETON.

Starting from the foot of State street, a bulkhead and a dam run out into the stream about 250 feet from the north shore; and then a dam runs diagonally down stream for 700 feet to within 400 feet of the south shore. From this a stone retaining-wall, called the pier, runs down stream for 800 feet, there uniting with the south bank. The dam and the pier are built on the most substantial plans by the government, with stone from the Kaukauna quarry already mentioned, and are very fine structures. The bed of the river is hard limestone. From the foot of this stone pier starts the ship-canal. The available water-power of the upper level is from a race along the north shore at that end of the dam, from the ship-canal, and from the stone pier.

FALL AND POWER.—At the dam the available head averages 10 feet, but at the foot of the stone pier 16 feet is the usual head; and at a manufactory about 1,400 feet down from the dam, on the north bank, they claim to have an average head of 18 feet. The average available head is 16 feet, and with this head the ordinary low-water theoretical power has before been given as 4,538 horse-power; but of course there is a large portion of the year when it is much greater. The extreme variation of the head is 3 feet; the ordinary variation, about 18 inches. This is due to various causes. A low stage of water decreases the available head, owing to the mills drawing it down, and the flash-boards, when put on the Neenah dam, have also the effect of lowering the head. The wind, when blowing strong and continuously, influences the discharge from the lake, and hence affects the head at Appleton somewhat. Then there are fluctuations due to the shutting down of the Neenah and the Menasha mills, and it is said that on Sundays the head at Appleton is lowered a foot from that cause. There is no trouble from anchor ice, because it is all still water above this level; but there is difficulty sometimes from slush ice breaking off from the solid portion and choking the racks. With the north-shore race there is a difficulty from ice, which is mentioned in describing it.

NORTH-SHORE RACE.—This race is 600 feet long, and from 50 to 60 feet wide. Starting from the abutment of the dam, it runs close to the river, and between it and the river, partly built out into the water, are the mills. The access to these by team is over the canal, which is covered with planking supported by a framework of posts. The ice which passes into the canal lodges against these, and sometimes there is trouble from the flow being obstructed by it, and the head lowered.

As shown by the map, there are four mills upon the canal proper, all of them extensive. No. 1 is the Appleton Paper and Pulp Company's mills, controlling 500 horse-power, and drawing direct from the pond; No. 2 is the Kimberly, Clark & Co. flouring-mills, with a capacity of 500 barrels per day, using from 100 to 160 horse-power; No. 3 is the Kimberly, Clark & Co. paper-bag mill, which was being built in the spring of 1881, and will probably have a capacity of from seven to nine tons of paper in twenty-four hours; and No. 4 is the Atlas paper-mills, with a capacity of ten or twelve tons in twenty-four hours. The latter are supplied by the Atlas wood-pulp mills, on the opposite side of the river.

There is one more industry fed from this canal, and that is No. 5, the Appleton manufacturing works, which produce agricultural implements. They are situated on Water street, which skirts the bluff, are 1,400 feet down stream from the dam, and are supplied with water by a flume 700 feet long, leading from the end of the canal. This flume, which runs underground along Water street, is 4 feet in diameter, made of 2-inch pine plank, 6 inches wide and 16 feet long. The sections, of 16 feet in length, are connected by wrought-iron bands 4 inches wide and a quarter of an inch thick. Beside these there are hoops of $\frac{3}{4}$-inch round iron encircling the flume at intervals of 18 inches. This flume is always full of water under pressure, and the head at the wheel pit is 18 feet on the average. They use 45 horse-power by means of an American turbine 3 feet in diameter. There is no engineering difficulty in the way of continuing the canal several hundred feet beyond its present length, but the power at a low stage is already pretty well taken up, either used or leased, and it is hardly probable that this improvement will be made, as there are better localities to be mentioned for utilizing the remaining power. Under the title of "Legal condition of the water-power" it was stated that the Green Bay and Mississippi Canal Company had the right to all power drawn from the head of each rapid, but that there were exceptions where long-established usage claimed recognition. This north-shore race is one of those exceptions. A wing-dam improvement was made before the ship-canal was commenced. An official of the company said that the mills did not lease from it, and no claim was made because of long possession. The Atlas Paper and Pulp Company's mill has a side-track running to its rear, while all the lines along the river at Appleton pass in front of the mills along the north-shore race.

LONG PIER.—The power used on the south shore is almost entirely taken from this pier. The land along the canal is owned by the Green Bay and Mississippi Canal Company, and all the power taken from the upper level on the south shore is leased from them.

Along the stone pier is a series of lots, 50 by 100 feet, some sixteen or seventeen in number, owned by the Green Bay and Mississippi Canal Company. The foundation of this pier is solid limestone, and these lots are partly natural, partly built out into the stream. The average head of water varies from 12 feet at the head of the pier to 16 feet at the lower end. The water is taken through arched openings in the stone pier direct from the large bay at the head of the ship-canal. There can thus be no difficulty from drawing down the level, since the race is not large enough. There are ten of these openings in the pier, some $13\frac{1}{2}$ by 6 feet, and others 15 by $7\frac{1}{4}$ feet. Two buildings use this power, both situated on the lower half of the pier; but they are large, and absorb pretty much all the room there. These are No. 6, the Atlas Paper Company's pulp-mills, and No. 7, the Western wood-pulp mills, the latter being owned by the large firm of Bradner, Smith & Co., of Chicago. The former supplies mill No. 4, across the river. The Atlas Paper Company are entitled to 1,000 horse-power at their mill, of which they use 700, and also have the control of the power from them up to the upper end of the pier, amounting to 1,500 horse-power. Thus the lots along the pier are pretty much all taken up. No. 7 uses from 600 to 700 horse-power. Each of the mills has four wheels, under 15 to 16 feet head.

The mills are situated 12 or 15 feet from the pier, and between them and the pier are wooden bulkheads at the openings in the latter. Each mill has a wing-dam running out into the river 50 feet or more, and then down

stream a short distance. By this contrivance the river is prevented from running in on the wheels, and a greater head is maintained. The wing-dam of No. 6 extends outside of No. 7, and a side-track of the Milwaukee and Northern railroad runs up to the mills, between them and the river. A wagon-road leads down to the middle level below, and also a bridge runs straight across the river to the Atlas Paper Company's mill, on the north-shore race.

SHIP-CANAL.—It now remains to describe the power upon the ship-canal from the upper level. A description of this canal has already been given, and, as previously stated, the Green Bay and Mississippi Canal Company has the right to draw water from the government canals at any point, provided they do not interfere with navigation. Hence they possess valuable power from the ship-canal, but there is only a small amount used at the extreme lower end of Grand Chute island. There are three locks on this canal: one at the foot of the stone pier, with 7¾ feet lift; one in the middle of the canal, with about 10¼ feet lift; and one at the foot, with 11 feet lift, and as the mills use from just above this last lock, they get a head nearly equal to its lift. No. 27 is a tannery, with about 10 feet head available; No. 28 is a hub and spoke factory, with about the same head; and No. 29 is a flouring-mill, with about 11 feet head, not now running. Nos. 27 and 28 discharge into the south channel, which is used as a tail-race by the mills on the middle level, while No. 29 discharges into the river direct. These use only a small amount of power.

UNUSED POWER.—As to unutilized sites at the upper level, it may be said that the most of them are upon the ship-canal. There are several unused at the stone pier, but they are already under the control of the manufactories now existing.

The ordinary low-water power of the upper level is popularly considered to be 5,000 horse-power, but with the ordinary low-water flow given by the engineers the theoretical power is 4,538 horse-power. Now, there cannot be less than 3,500 horse-power, at the lowest estimate, either used or under the control of the mills already upon the upper level, leaving 1,000 horse-power yet to be disposed of. It is true that for a large portion of the year there is much more power than this, but the estimates are made for an ordinary low stage. If this 1,000 horse-power were divided among industries, each using 50 horse-power, it would supply twenty of them, using, say, twenty lots of 50 feet front, and there is sufficient room on the Green Bay and Mississippi Canal Company's lots for this.

There are available sites at the right hand of the upper lock, where mills could take water from above the lock and discharge below, getting about 8 feet head, but the bulk of the available lots are on the flat between Mill street and the canal, and above the main street, which crosses Grand Chute island to the bridge. There they have room for twenty lots, each with a 50-foot frontage and 150 feet depth. In connection with this there is a scheme which would considerably alter the conditions of the upper and middle levels.

Thus far all of the tail-races of the upper level, except in the case of the small manufactories at the end of the ship-canal, empty into the river above the middle dam.

The Green Bay and Mississippi Canal Company have a plan, not yet carried out, however, for the utilization of the remaining power of the upper level, on the series of lots just mentioned, in a way which would discharge the water below the middle dam into the lower level. This would diminish the discharge through the middle level, but would give the Green Bay and Mississippi Canal Company an increase of head nearly equal to that available at the middle level, viz: 10 feet, giving them a total head of 25 or 26 feet. The plan is to build a conduit, which, starting from the pond just to the right of the upper lock, shall pass under the canal and then parallel to it, being always filled with water under hydrostatic pressure. The mills shall draw from it, and discharge into a tail-race leading into the south channel, and their wheels would be under a pressure due to a head of 25 feet. The power left to be utilized in this way is 1,000 horse-power at 16 feet head, requiring a flow of 551 cubic feet per second. The same volume of water at 25 feet head would give 1,563 theoretical horse-power, which is the power that would be available by this improvement.

It would hardly be practicable to run the large tail-race up to the upper six of the lots without considerable expense, because they extend out into the river; so they would only have the head of the upper level, viz: 16 feet. Supposing them to use 50 horse-power each, they would take 300 horse-power and a flow of 387.7 cubic feet per second to be utilized at the 25-foot head. This would give a theoretical power of 1,100 horse-power which, distributed among the fourteen remaining lots, would supply 78 horse-power to each.

The main lines of the Milwaukee and Northern and the Milwaukee, Lake Shore and Western railroads pass between these lots and the river; Mill street also runs alongside of them, giving easy communication with the town.

MIDDLE LEVEL AT APPLETON.

As already described, the middle level is independent of the government works, which connect the upper and lower levels by the ship-canal. This level is under the control of the individuals directly interested in the power, and is created solely in the interests of water-power. The Green Bay and Mississippi Canal Company make no claim upon the powers that may be obtainable at this level, and it comes under the fourth class of powers mentioned in describing the legal conditions of the Appleton water-power.

The dam is 2,400 feet below the upper dam, and is in itself about 450 feet long; but this does not represent the total width of the river at that point, which amounts to about 950 feet just above the dam. Below the dam the

width is about 650 feet from bank to bank. This dam is a timber frame construction, designed and built by Captain N. M. Edwards, and is described in the section devoted to that subject. The bed is limestone. From the north end of this dam a race leads down the north shore; at the south end the dam abuts on Grand Chute island, and from the basin at this end supplies West's hydraulic canal, as well as several manufactories which feed directly from it. These, with the exception of a power at the north abutment of the dam, are the three methods, and the only available ones, of using the power of the middle level.

History of the middle level.—Previous to 1877 there was no dam across the stream at the middle level, but wing-dams passed up stream several hundred feet from each of the abutments of the present dam, deflecting the water, the one into the race on the north shore, the other into the basin at the south end of the dam. In 1870 Mr. Edward West built the West's canal, leading from the basin down the island. Later, the individuals interested in the powers of the middle level formed a company for building and maintaining a dam, and in 1877 the present dam was constructed, and Mr. West's wing-dam removed. The other wing-dam, however, remains. This is the condition of the middle level to-day.

Mr. West is the most prominent owner on the middle level, and is identified with the early history of Appleton, having bought Grand Chute island when the forest covered it. He then predicted that the day would come when a ship-canal would pass through the valley and the water-power would be developed.

Fall and power.—The average available head of the middle level is 10 feet, and with the total flow of the river, which it practically has, under the present conditions of the upper-level improvements the theoretical ordinary low-water power is 2,836 horse-power. If the contemplated improvement at the upper level just described is made—that is, using 1,563 horse-power at 25 feet head, discharging below the middle level—then the ordinary low-water discharge over the middle dam will be 2,500−551=1,949 cubic feet per second; but if the improvement is made using 300 horse-power at about 8 feet head, and 1,100 horse-power at 25 feet head, then the discharge over the middle dam in ordinary low water will be 2,500−387.7=2,112.3 cubic feet per second. In the first case, the power would be 2,211 theoretical horse-power; in the second case, 2,396 theoretical horse-power.

Thus, there are three conditions, to one of which the power of the middle level will probably be subject:

1. A continuation of the present situation, in which, practically, all the discharge of the river goes through the middle level, giving an ordinary low-stage power of 2,836 theoretical horse-power.

2. An improvement on the upper level of 300 horse-power at about 8 feet head, and 1,100 horse-power at 25 feet head, in which case the ordinary low-water power of the middle level will be 2,396 theoretical horse-power.

3. An improvement on the upper level of 1,563 horse-power at 25 feet head, in which case the ordinary low-water power of the middle level will be 2,211 theoretical horse-power.

Of course it would be possible to use the surplus power of the upper level from the north-shore race, as already mentioned, in which case the first condition would occur, or from the lower end of the ship-canal, when the equivalent of the third condition would be the result. Of all these it is probable that for some time the first condition will be the state of the power, with a prospect in the future of the second condition occurring; that is, the ordinary low-stage power of the middle level will be 2,836 theoretical horse-power for some time, with the chances of its being reduced in the future to 2,396 horse-power, or perhaps to 2,211 horse-power.

The variation in the head is the same in character as at the upper level. As the river is a mass of rapids for several hundred feet from the upper dam to the middle level, there is a chance for anchor ice to form, and the manufacturers on the middle level are troubled with this to some extent in very cold seasons.

In order to keep the water as much as possible at a uniform level in the pond and avoid the expense of extensive gates and gearing, the method was taken of using what are called needles, as described in the section on dams. They consist of scantling about 3 inches wide, which are thrust down at the crest of the dam, and thus the width of the overflow is diminished. A man is employed to attend to this matter, and to regulate the waste over the dam according to the amount of water used. The water surface can be kept within a variation of 3 inches. When all the mills are running, and the water is not high, the needles are all put in, and as the mills shut down he goes along and removes some of them. There is always a space of about 75 feet at the north end of the dam where no needles are placed.

The powers of the middle level at Appleton are divided for description thus: North-shore race (middle level); West's canal; the basin. The latter is merely a portion of the pond.

North-shore race.—This race (middle level) is about 800 feet long, and runs down stream from the dam between the river and Water street. In the upper part of its course the race is of fair size, but in the lower third it is hardly more than 15 feet wide.

The old wing-wall, which collected the water before the dam was built, still exists, and serves as a bed for the railroad track to the rear of the Appleton paper and pulp mills, on the upper level. This wing-wall extends up stream about 1,500 feet, and there is a waste-weir connecting the waters on each side of it. Extending, as it does, so far up stream, it acts to a great extent independently of the middle dam, as was the case before the dam was built. It collects a portion of the tail-water from the mills on the north-shore race (upper level), but it is largely supplied by the river direct. The head is ordinarily maintained as good as in the pond proper, and often, as was the case when visited, there is a flow, with a head of several inches, through the waste-weir in the wing-dam into the pond.

About 250 feet below the dam the highway bridge crosses the river to Grand Chute island. The race, above the crossing being planked over, a broad space is made for the approach of wagons, and the railroad tracks pass along the rear of the mills at the upper portion of this race. The head varies from an average of 9 feet at the upper end of the race to 12 feet at the foot.

The mills are as follows, beginning at the upper end of the race: No. 19, a planing-mill, fed from the pond, and independent of the race and wing-dam, but mentioned here because of its locality, using only a moderate power; No. 20, Appleton flouring-mills, Mr. S. R. Willy, proprietor, the wheels of which are old-fashioned and very wasteful of water; No. 21, Lawrence flouring-mills of Hauert & Wambold; No. 22, Outagamie flouring-mills, Cross & Willy proprietors; and No. 23, Riverside flouring-mills, M. T. Boult, proprietor. The power used in Nos. 21, 22, and 23 averages from 100 to 150 horse-power each. No. 24 is T. W. Brown's pump factory, using 30 horse-power, and having a center-discharge wheel of 7 feet diameter under about 10 feet head; No. 25, a machine shop, with 12 feet head; not running in the winter of 1880–'81; and No. 26, a small woolen-mill, with about 12 feet head. This is the last power used upon the race. Between No. 23 and No. 24 there are about 300 feet of unoccupied mill-sites, and about the same distance between No. 24 and No. 25.

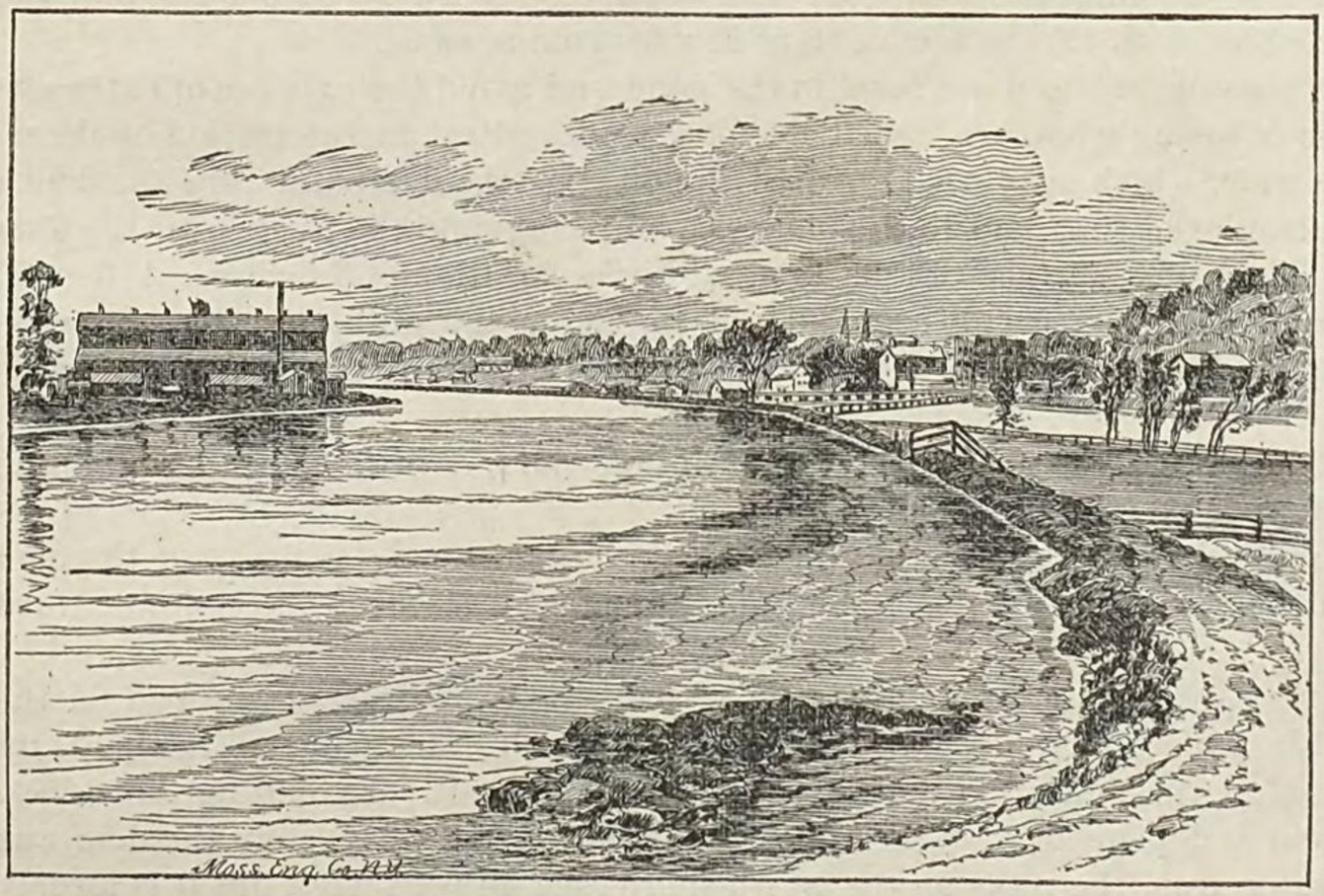
The race could be extended several hundred feet farther down the river and the mills could be built out over the stream, as is now done, because the bluffs crowd the race near the river's edge. That is a great disadvantage about the sites at the lower end of the race, there not being much room for transportation. As the mills are built out over the river on piles, the same scheme is used for obtaining a tail-race as at the pulp-mills on the upper level. Starting above the mill, a wing-dam runs out diagonally into the river, and then down stream, keeping the flow of the river away from the wheels.

There is plenty of room on Grand Chute island for using the unutilized power of the middle level, reckoned at an ordinary low stage of water, and the sites are much more favorable than along the lower part of the north-shore race (middle level).

THE BASIN.—The bridge from the main street over Grand Chute island crosses the river about 250 feet below the dam at the north end, but at the island extremity the dam is not over 150 feet above the bridge. The basin, if it may be so called for distinction, runs from the dam down to the street and there stops. West's canal starts from the northern corner of this basin. There are four manufactories using water direct from the basin, two of them above the street and two below, and the head averages 10 feet.

No. 8, above the street, is the machine and repair shops of Proctor, Wetlaufer & Co., using, on the average, 10 horse-power. Their head-race runs under No. 9, and their tail-race discharges into the south channel. No. 9 is the Champion steel horse-nail works. They use 75 horse-power, and their tail-race unites with that of No. 8. No. 10 is the Valley Pulp and Paper Company. These pulp-works were started in the end of the year 1880, and the intention is to manufacture paper later. They expected to use 325 horse-power. No. 11 is Billings & Morrison's hub and spoke factory. This, as well as Nos. 13 and 14, has a wooden bulkhead running down from the basin along the upper end of the south channel, into which the wheels discharge. The power used by No. 11 is 40 horse-power. No. 13 is the Appleton foundry and machine-shop, Morgan & Bassett proprietors. They use about 60 horse-power.

WEST'S CANAL.—This canal extends from the basin down Grand Chute island for about 1,700 feet, running nearly parallel to the south channel, as also to the main channel of the river, and there is a bend of 10 or 15 degrees in the middle of its length. The head of the canal is at the upper, and the foot at the lower bridge, leading to Grand Chute island. It is really built up upon the island, as both sides and the end are formed of embankments. The cost of construction was about $40,000. The embankments are 12 or 15 feet high at the lower end, and the canal bed is excavated in the gravel-bed formation of the island. The canal is 130 feet wide, and its bed is 17 feet below the crest of the embankments. These are earth and stone, 45 feet wide at the base and about 10 feet across the crest, which is 2 or 3 feet above the water surface. At the bulkhead there are four openings, each 22 feet wide, with a depth of water in an average low stage of 8½ feet, and between the openings are three cribs, 7 feet through. The total bulkhead opening is 88 by 8½ feet in an ordinary low stage, or 748 square feet, and the openings can be closed with "needles", if it is necessary



APPLETON, WISCONSIN: VIEW OF WEST'S CANAL FROM THE LOWER END

at any time to shut off the water and drain the canal. The head averages 10 feet. The manufactories are situated back of the embankments, those on the south side discharging into the south channel, and those upon the north embankment having tail-races leading into the main river.

The manufactories upon the north side are No. 14, Appleton woolen-mills, owned by Hutchison & Co. Their warehouse is No. 12, situated on the upper street, crossing the island. In the summer of 1881 this mill was burned, but the proprietors intend to rebuild on a much more extensive scale. No. 16 is the Appleton Chair and Bedstead Company, Mr. Atkinson, proprietor, which was burned with No. 14. It used 40, but was entitled to 60 horse-power.

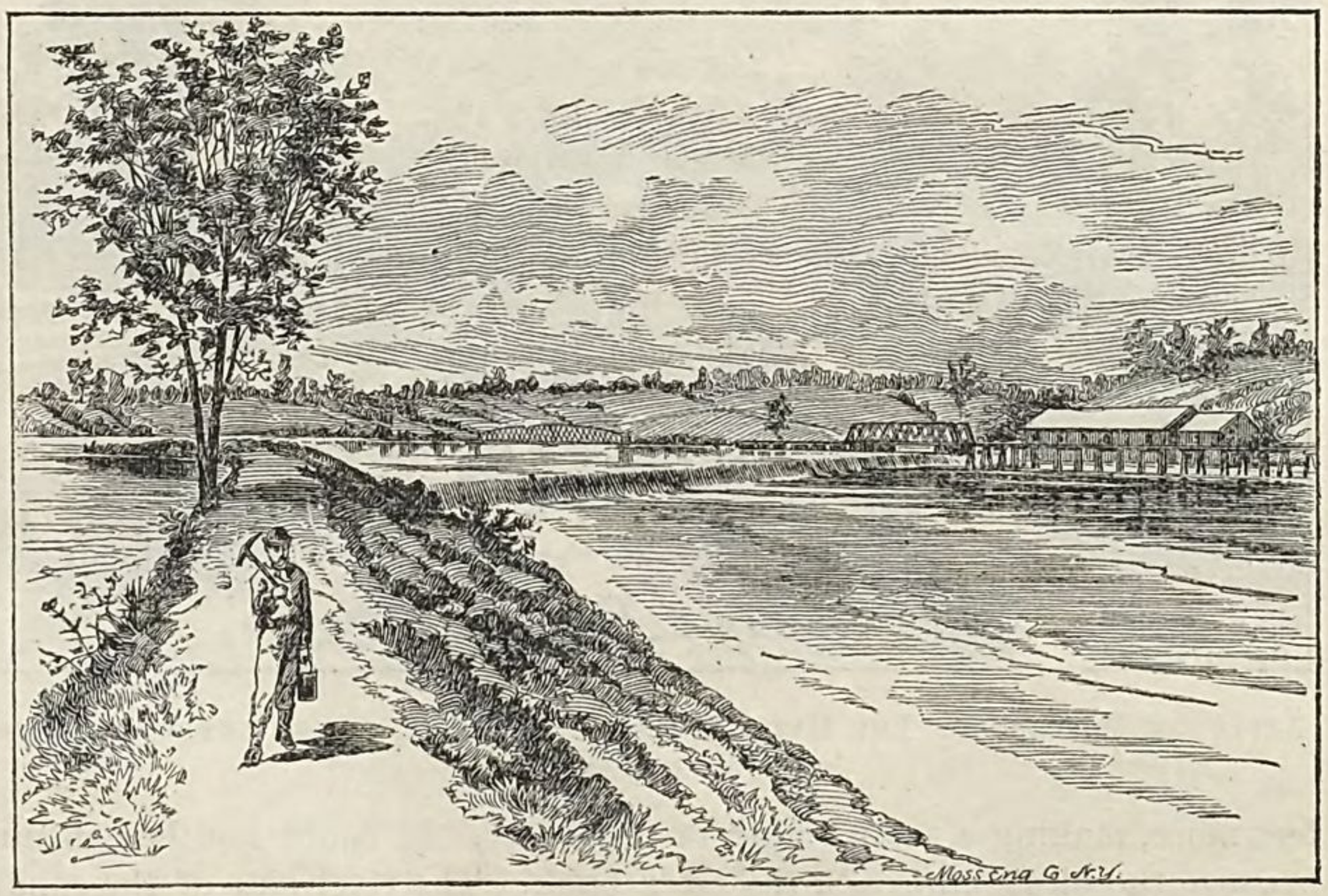
The manufactories upon the north embankment are No. 15, Appleton hub and spoke factory, Marston & Beveridge, proprietors, using 80 horse-power under 10 feet head; and No. 17, Fleming & Co.'s flax-mills, situated near the lower end of the canal. They were completing the building of these mills in the spring of 1881. This is the introduction of an industry new to the Fox River region. Just west of No. 17 a large paper-mill was being erected in the summer of 1881.

The remaining building using power from West's canal is the works of the Appleton Furnace Company, No. 18, of which Mr. A. L. Smith, of Appleton, is president. Its capacity in 1880 was from 35 to 40 tons of pig iron produced per twenty-four hours, extensive use being made of the rich Menominee ores. Situated on the street opposite the foot of the canal, they take the water in an underground flume, and control 400 horse-power. This is the farthest down stream of all the powers used from the middle level.

There is, of course, abundant capacity in this canal for a greater flow than is now used, and, as the map shows, there is a large amount of unoccupied room. At a low estimate, there must be 2,500 feet unoccupied facing on the canal, and the lots running back from it are 150 to nearly 300 feet in depth, giving fine building sites. Railroad tracks of different companies run along both sides of the canal, and the facilities for approach by team at either end are excellent. Undoubtedly the best water-power sites to be obtained on the middle level are upon this canal, and indeed, all things considered, they are hardly to be excelled at Appleton.

LOWER LEVEL AT APPLETON.

This level, as stated previously, is controlled by the government for purposes of navigation. The dam is situated just below the lower bend of the river, 4,600 feet below the middle dam and 1,300 from the lower end of Grand Chute island. The river just above is 485 feet wide. The government dam, 417 feet long, runs diagonally down, at an angle of about 45 degrees with the channel, to an embankment which runs down stream 600 feet to the lower bridge of Appleton, and back of this embankment is the ship-canal of the lower level. The embankment continues about 175 feet below the bridge to the one lock of the lower level. At the bridge the river widens out on the north shore to 600 feet across.



APPLETON, WISCONSIN: LOWER DAM, FROM THE SHIP-CANAL BANK.

For the first 1,500 feet below the dam there is a natural fall in the river of about 3 feet. Below the lower bend the course of the river is northeast, so that what was the north bank on the other levels is the west bank at the lower level, and the former south bank becomes the east bank. The river runs close to the west bluffs, except right at the dam, but on the east shore is a flat, 200 to 300 feet wide, between the river and the bluffs. There are four methods here of utilizing the power. They are: From the west end of the dam, from a west-shore race, from the ship-canal, and from the canal on the east shore, belonging to the Telulah Water-Power Company.

FALL AND POWER.—The head at the dam is only 7 feet, but farther down it is greater, and the average available head is about 10 feet. They get the whole flow of the river, and there is a prospect that this will always be the case. The ordinary low-water power of this level at 10 feet head is 2,836 theoretical horse-power, but of this only a small portion is now used. The fluctuations to which the powers above are subject are also experienced here, and there must be some additional variation in low water, due to the shutting down of the mills upon the upper level. The power No. 30, taken direct from the pond at the west abutment of the dam, is used by Messrs. Rose & Heath's saw-mill. The head is about 7 feet.

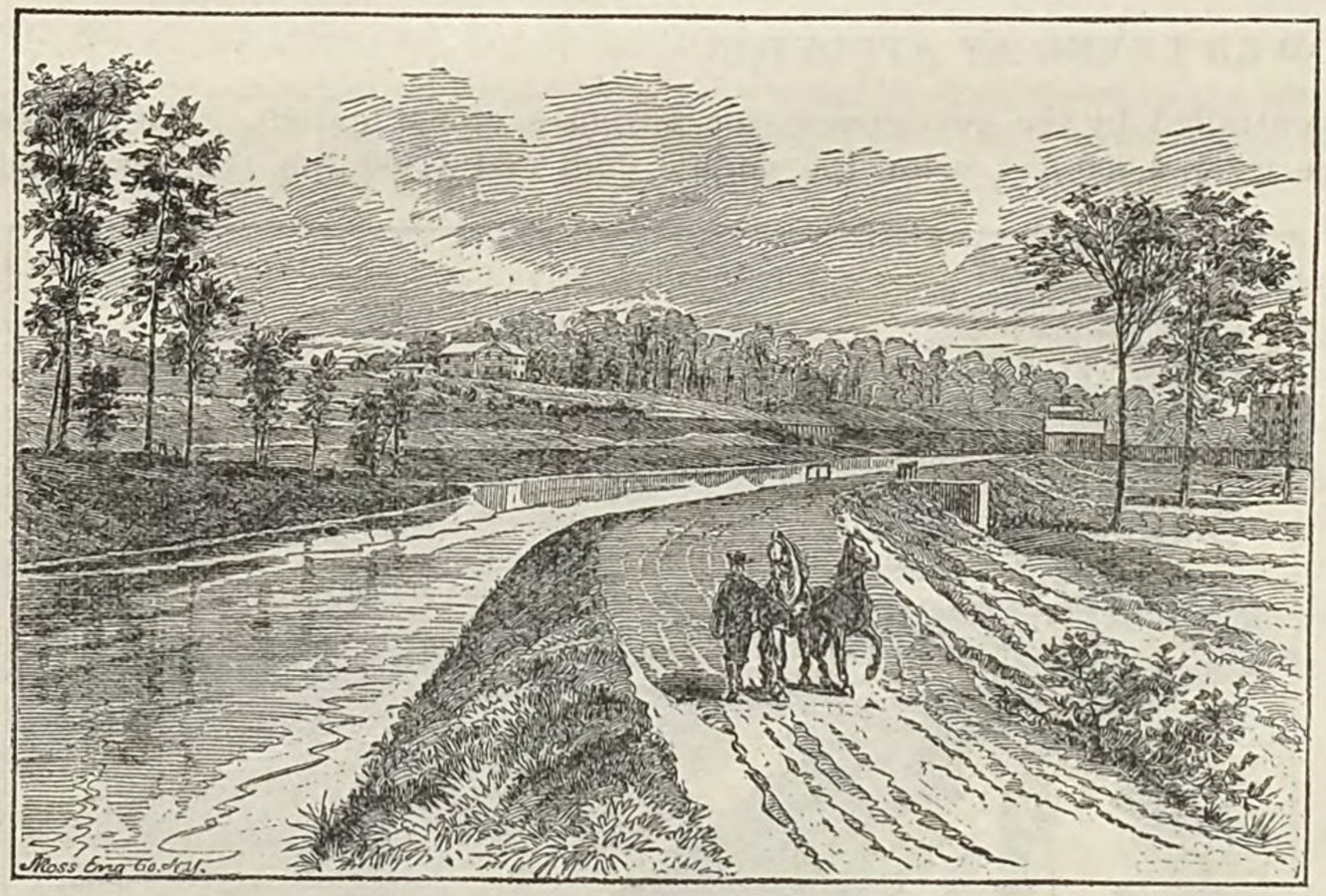
WEST-SHORE RACE.—The west-shore race starts from the pond, 450 feet above the dam. In 1878 it was extended 25 feet wide and 850 feet long down to about 150 feet above the bridge. In 1880 Messrs. Heath & Brothers, the owners, sold out to the Green Bay and Mississippi Canal Company, who now hold it, and in the spring and summer of 1881 they were busy making surveys for the extension of the work. By this extension the capacity will be much increased, and the plan has been proposed of running the race under the street and supplying mills below the bridge. The bluffs rise steep from the water, so that it would be necessary to build these mills out into the stream. As it is now, they own below the dam 480 feet of facing on the canal, and by building out into the bay on the west bank, already mentioned, they would have nine lots of 50 feet face and 150 to 180 feet depth. The Chicago and Northwestern railroad track runs past these lots. There are at present two manufactories upon the lower part of the race: No. 31, Dickerson's shutter works; and No. 32, Baum & Huhn's custom flouring-mill. The head at these mills averages about 8 feet.

The west-shore race is entitled to nearly one-fourth of the flow of the river, which would give it, at 10 feet head, 709 theoretical horse-power, or with an efficiency of 75 per cent., 532 available horse-power at an ordinary low stage. If this one-fourth flow is used at the upper part of the race with an average head of 8 feet, it will only furnish 567 theoretical horse-power, or 425 available horse-power. This would be sufficient to utilize all the lots with the smaller class of manufactories.

The only remaining manufactory upon the lower level is at the lock of the ship-canal, and is the only really good location on the canal. It is No. 33, Richmond Brothers' paper-mill, and has a head of about 10 feet.

HYDE & HARRIMAN CANAL.—The canal of the Telulah Water-Power Company, on the east shore, has been known as the Hyde & Harriman canal. The case has been described under the heading of "Legal conditions of the Appleton water-powers".

Mr. Welcome Hyde and Judge J. E. Harriman, two well-known citizens of Appleton, owned the land, and the Green Bay and Mississippi Canal Company owned the power. These two gentlemen and the members of the Green Bay and Mississippi Canal Company, *as individuals*, organized themselves into the Telulah Water-Power Company and began improvements. Under the superintendence of Judge Harriman, ground was broken on August 15, 1880, and on November 13 of the same year the canal was completed. (*a*)



APPLETON, WISCONSIN: THE HYDE & HARRIMAN CANAL, LOWER LEVEL, LOOKING UP STREAM.

It has already been said that on the east shore the bluffs recede from the river at the lower dam and leave a flat from 300 to 450 feet wide, but about 2,400 feet below the dam they come close to the water's edge again. The canal starts at the head of the ship-canal, 600 feet above the bridge, and skirts the line of the bluffs all its length. For the first 1,500 feet it is straight, then, owing to the formation of the bluffs, it bends toward the river at an angle of about 40 degrees with its former direction, and continues straight for 750 feet more, making a total length of 2,250 feet. It could not be continued further without considerable expense, because the bluffs approach the river bank. The river side of the canal is an earth embankment all the way. At the head of the canal the cross-section is 120 by 7 feet; at the bridge it contracts to 80 feet in width, but is 11 feet deep; and in the lower portion the average width is about 60 feet. The head varies little at different points on the canal below the bridge, and averages 10 feet. At the head of the canal is a bulkhead for shutting off the water, which will be described in the section devoted to the construction. Practically, three-fourths of the flow of the river can be used in this canal, which, at an ordinary low stage and 10 feet head, will give 2,127 theoretical horse-power, or, with an efficiency of 75 per cent., 1,595 available horse-power. There are as yet no manufactories upon this canal, and of course the method of utilization will be to erect mills on the flat and facing it. The land along the upper portion of this canal is said to be owned by other persons, but the company owns twenty-five lots from the lower end of the

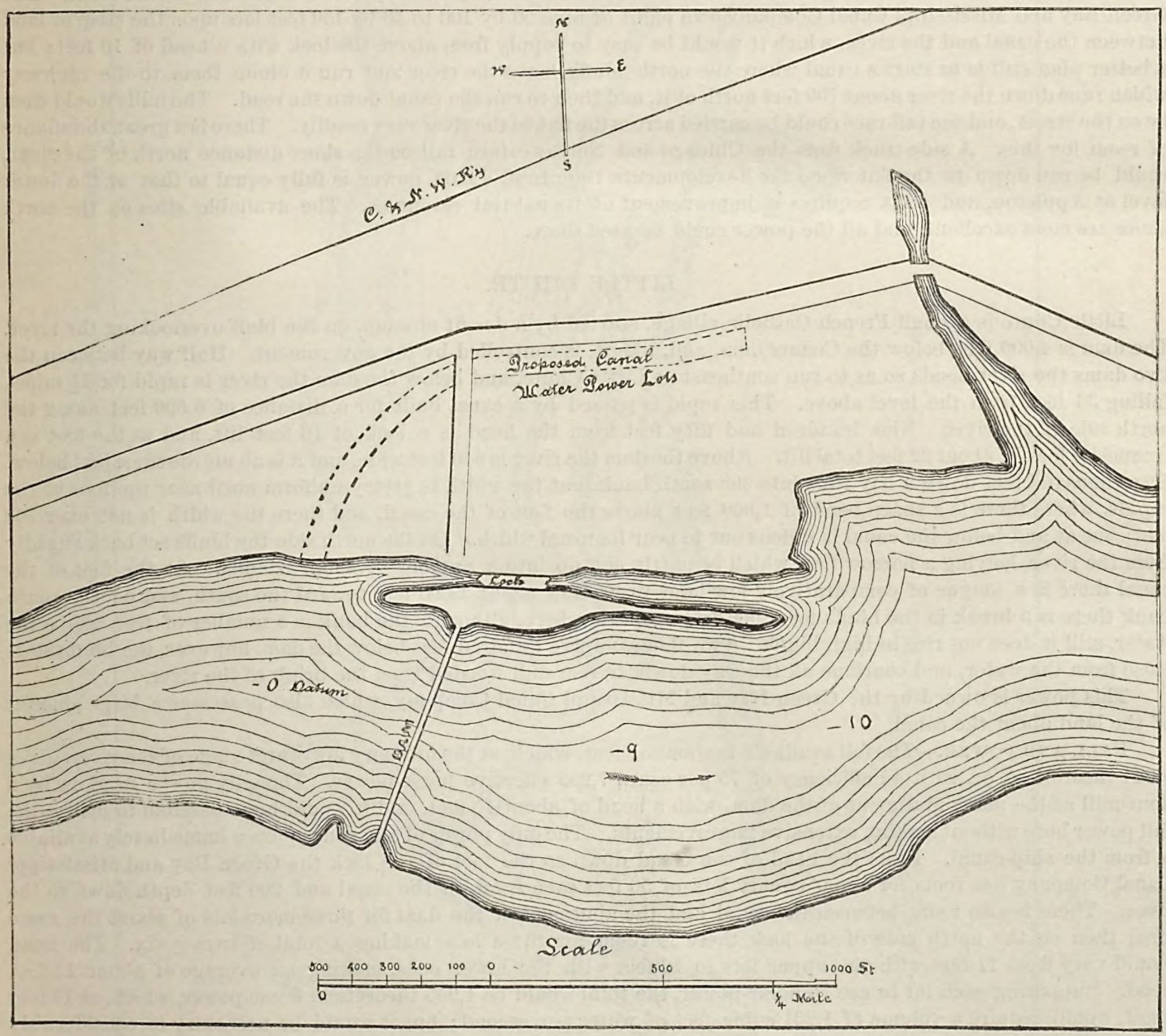
a Since writing the above, information has been received (September, 1881) that the Green Bay and Mississippi Canal Company has purchased the stock of the persons before interested with them, excepting a very small amount still held by Judge Harriman. Thus the Green Bay and Mississippi Canal Company now practically controls the lower level at Appleton, and will probably use the greater part of the water on the east side of the river.

canal up, with a frontage on the canal of 50 feet each, and a depth out to the river in most cases of 300 feet. The power would be sufficient at an ordinary low stage to supply each lot with 85 theoretical horse-power, but it is more likely that the power will be, to some extent, concentrated in establishments like wood-pulp mills, using 500 horse-power or more. The intention is to use the embankment for a wagon-road to the mills.

The Milwaukee, Lake Shore and Western railroad passes near, and the track of the Chicago and Northwestern railroad is just across the river; and so soon as the business will warrant it these roads will lay side-tracks along the canal lots, for which there is every facility.

THE RIVER FROM THE LOWER LEVEL AT APPLETON DOWN TO CEDARS.

In the engineering reports the distance is given as being 3 miles, but, measured on the United States engineers' map, it is 3.6 miles along the course of the river from dam to dam. In this distance the general course of the river is nearly northeast, but along the lower half there is a tendency to bend more to the east. The channel is gently winding all the way, and the navigation is by slack water from the Cedars dam to the foot of the canal at the lower level of Appleton. The clay bluffs, which for almost the whole distance spring close from the river's brink, are well wooded. The average width of the river in the distance named is about 600 feet; and in one or two places it widens out to 900 feet, and then again narrows to only 400 feet across.



LOWER FOX RIVER AT CEDARS, WISCONSIN.

CEDARS.

At Cedars the course of the river is nearly east. The bluffs upon the south shore rise near the river, but on the north a small creek enters, and the north-shore bluffs, which have been following close along the river bank, sweep around and run up this stream for a distance, and then again return to the river edge below, leaving a flat of 30 or 40 acres, through which the creek runs to the main stream.

The dam is situated about 1,000 feet below where the north bluff recedes from the river. Starting from the north shore, it runs straight across the current to the north bank. Two hundred and fifty feet above the dam the government canal starts from the Cedars level and runs 950 feet below the dam to the slack water of the Little Chute level, and about opposite the dam is the one lock, with a lift of 10 feet. The river immediately above and below the dam is about the same width as its length, which by the United States engineers is given as 810 feet. Below the canal the north shore recedes at the mouth of the creek, making the width for a short distance about 950 feet. There are no manufactories yet on this level, and there is no town; nothing but the dam and the lock.

FALL AND POWER.—The available head is about 9 feet, which, at an ordinary low stage, will give 2,553 theoretical horse-power, or, with an efficiency of 75 per cent., 1,915 effective horse-power. This power is, of course, owned by the Green Bay and Mississippi Canal Company.

While it would be possible to utilize the power, in part at least, upon the north bank, it is evident at a glance that the proper direction for improvement to take is to utilize the power upon the north side of the river. The Green Bay and Mississippi Canal Company own eight or nine 50 by 100 to 50 by 150 feet lots upon the strip of land between the canal and the river, which it would be easy to supply from above the lock with a head of 10 feet; but a better plan still is to start a canal where the north bluffs leave the river and run it along them to the highway which runs down the river about 700 feet north of it, and then to run the canal down the road. The mills would then be on the street, and the tail-race could be carried across the flat to the river very readily. There is a great abundance of room for this. A side-track from the Chicago and Northwestern railroad, a short distance north of the river, could be run down to the flat when the developments require it. This power is fully equal to that at the lower level at Appleton, and all it requires is improvement of its natural resources. The available sites on the north shore are most excellent, and all the power could be used there.

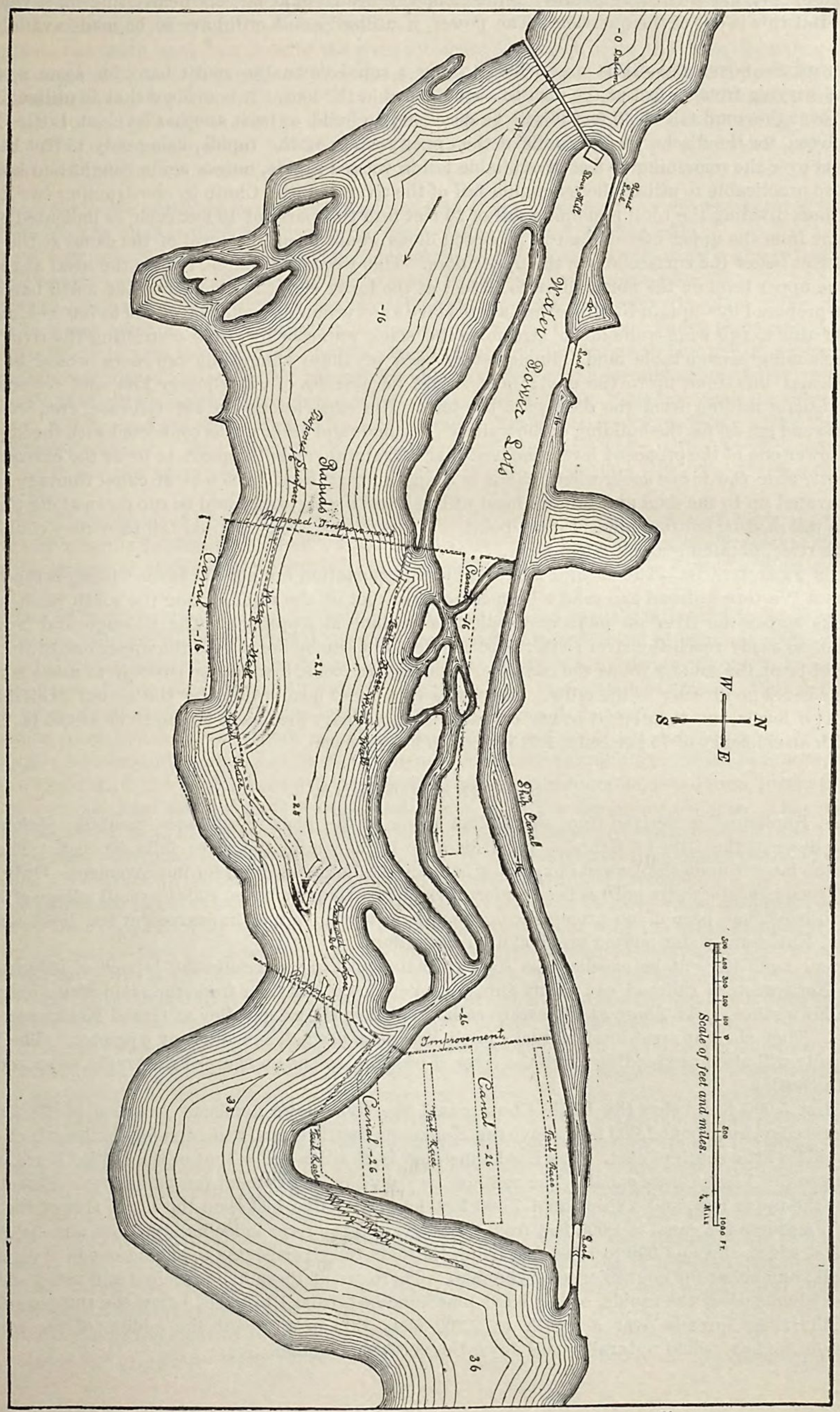
LITTLE CHUTE.

Little Chute is a small French Catholic village, started by a Jesuit mission, on the bluff overlooking the river. The dam is 4,000 feet below the Cedars dam, and, like it, is controlled by the government. Half way between the two dams the river bends so as to run southeast at Little Chute, and below the dam the river is rapid for 1½ miles, falling 38 feet from the level above. This rapid is passed by a canal built for a distance of 6,500 feet along the north side of the river. Nine hundred and fifty feet from the head is a lock of 16 feet lift, and at the foot is a composite lock of about 22 feet total lift. Above the dam the river is 840 feet wide, and it is about the same just below. Two thousand feet down a bay runs into the south bank, but the width is pretty uniform until near the foot of the rapids, where there is a sharp bend of 1,000 feet above the foot of the canal, and there the width is not over 700 feet; but at and below the canal it widens out to near its usual width. On the north side the bluffs set back slightly from the river, leaving a narrow flat, which is partly cut up into a number of small islands. At the foot of the canal there is a tongue of comparatively low land projecting about 1,000 feet toward the south, and on the south bank there is a break in the bluffs for 1,500 feet or more, where, although the bank is a number of feet above the water, still it does not rise in high bluffs. Two thousand five hundred feet below the dam, however, the bluffs start close from the water, and continue all the way down, to rise well wooded from the brink of the river.

This power is owned by the Green Bay and Mississippi Canal Company, which also possesses a large amount of the land about the canal.

FALL AND POWER.—The fall available is about 34 feet, which, at the ordinary low-water stage of the river, gives 9,644 theoretical, or, with an efficiency of 75 per cent., 7,233 effective horse-power. The only power used is by a flour-mill at the north abutment of the dam, with a head of about 11 feet, and it would be impossible to utilize the full power here without making extensive improvements. The only power of any consequence immediately available is from the ship-canal. From the head of the canal down to the foot of the lock the Green Bay and Mississippi Canal Company has room for about twenty lots of 50 feet each front on the canal and 200 feet depth down to the river. There is also room between the canal and the abutment of the dam for three more lots of about the same size; then on the north side of the lock there is room for three lots, making a total of twenty-six. The head would vary from 11 feet with the upper lots to 16 feet with the lower ones, making an average of about 14 feet head. Supposing each lot to use 75 horse-power, the total would be 1,955 theoretical horse-power, which, at 14 feet head, would require a volume of 1,231 cubic feet of water per second; but it would be necessary to considerably enlarge the canal before any such discharge as this through it would be permissible, on account of navigation. Provided the canal were sufficiently enlarged to permit the water to pass without interfering with navigation, and a sluice was built around the upper lock, manufactories could be built on the flat along the lower level for a distance of 2,000 feet or more, and be supplied from it, the head varying from 15 to about 18 feet.

If the canal was devoted to the interests of the water-power, and altered to suit the consequent conditions, a very extensive series of powers could be obtained; but the canal is for navigation, and this limits the utilization of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Tail Race

the water-power from it. If the canal were enlarged, the embankment raised, and the middle lock flooded out, a magnificent set of powers would be ready for use. At the foot the head would be about 34 feet, and by building a wing-wall and excavating a tail-race parallel to the canal the head would be very nearly that for several hundred feet above. But this is out of the question. The power, if utilized at all, will have to be made available in some other way.

IMPROVEMENTS POSSIBLE.—It is practicable to run a canal down the south bank for some 2,000 feet and utilize a head varying from 11 feet at the dam to about 20 feet at the foot. It is evident that to utilize the full flow of the river over the total fall of 36 feet it will be necessary to build at least another level at Little Chute, as is done at Appleton, for the discharge from mills at the upper portion of the rapids, using only 15 feet head, will go down the river over the remaining 19 feet of available fall in wasted rapids, unless again caught and held back for use. It is also practicable to utilize the remaining fall of the river at Little Chute by constructing two levels below the existing dam, dividing the total remaining fall of 20 feet into two parts of 10 feet each, as indicated on the map. The backwater from the upper one of the two proposed dams would be on the level of the canal at the foot of the first lock, 16 feet below the surface above the upper dam. This would, of course, reduce the head at the proposed canal from the upper level on the north shore to 16 feet at the lower end, the same as on the north bank.

The plan proposed by Captain N. M. Edwards is to leave an overflow on each dam of 600 to 700 feet, and from the extremities of this to run wing-walls down stream to the slack water below, thus restricting the river to 700 feet wide and reclaiming considerable land. Immediately back of these wing-walls tail-races would be excavated in the gravel and limestone up to the dam; next would be a series of water-power lots, and beyond these the water-power canals leading from the dam past the lots. The excavations for the tail-race, etc., would furnish excellent stone and gravel for the building of the walls of the canals and other works connected with the improvement.

For the lower one of the proposed levels the best place for improvement appears to be at the extensive flats on the north shore, near the lower lock, where there is a space for at least 3,000 feet of canal frontage. Tail-races could be excavated up to the dam and the full head utilized, and a wing-wall could be run down along the river, and behind this a tail-race be cut for mills at that point. Without this wing-wall and tail-race they could discharge directly in the river, obtaining about 8 feet head.

MEANS OF FREIGHTAGE.—The natural facilities for transportation are good at Little Chute, as the Milwaukee, Lake Shore and Western railroad can send a branch from the foot of the rapids along the south bank, and readily run side-tracks across the river on piers or trestles, as is done at Appleton. The Chicago and Northwestern railroad cannot so easily reach the river; still, as at Appleton, it can be done. As the upper one of the two levels proposed would be on the same level as the canal between the two locks, it would be possible to make a connection, so that vessels could go directly to the mills. Supposing that 9 feet head would be the actual available head at each of the two levels, the theoretical power of each at an ordinary low stage of the river would be 2,553 horse-power, or, with an efficiency of 75 per cent., 1,915 effective horse-power.

GRAND KAUKAUNA.

The name Kaukauna is derived from the Indian name of the place, *Kaukonnee*, meaning pickerel fishery. Well does it deserve the title of Grand. In a distance of one mile the river falls 50 feet. The power is undoubtedly the largest upon the Lower Fox, and it is in an excellent condition for improvement. Only since 1878 has any improvement of the water-powers been undertaken on an extensive basis, and the small village of Kaukauna, upon the north bank, has been of no prominence. Now, however, an era of improvement has been inaugurated, and the Grand Kaukauna water-powers are to claim recognition.

The railroad facilities will be excellent so soon as manufacturing warrants the laying of side-tracks. The Chicago and Northwestern railroad can easily run a branch down the river from the main road along the north side, and the Milwaukee, Lake Shore and Western railroad strikes the river valley at Grand Kaukauna on its way from the lake. They also can send branch tracks in all directions needed, as is done at Appleton. The Wisconsin Central Company will also be extending down the river, if possible, to have a share of the traffic, as soon as business will pay for the outlay.

For the first 5,000 feet below the Little Chute canal the river flows northeast between bluffs rising direct from the water's edge, but about 1,000 feet above the Kaukauna dam it turns, and runs for the length of the Grand Kaukauna rapids a little south of east. The Kaukauna dam is 2½ miles below that of the Little Chute, and makes slack water up to the Little Chute canal. The method used by the government for passing this 50-foot fall is to have a dam at the upper end, and a ship-canal 7,400 feet long, with five locks, on the north side of the river. In the middle of its course the canal is 1,000 feet from the river, and the river immediately above and below the dam is about 700 feet wide. From 1,000 to 1,500 feet below the dam the river begins to spread out in several channels between islands, numbered for convenience on the map. There are of these five principal and many smaller ones. Between these islands occur the rapids, over a hard limestone bed, from 1 to 6 feet below the surface soil. In the widest place the river spreads over a width of 2,200 feet; this is at about the middle of the rapids. The principal part of the flow would naturally pass down the northern channel.

Island No. 1, the largest, is also the highest one. It starts in a point 500 feet below the dam, and runs down stream 2,800 feet, with a maximum width of about 800 feet and an area of 27 acres. These islands are not much elevated above the river, and are, to a great extent, covered with a moderate growth of timber. The foundation of them all is the lime rock, forming the bed of the river.

The bluffs on the north bank run close to the river for about 1,400 feet below the dam; then they diverge from the river at an angle of about 35 degrees, and pass along the canal for about 3,000 feet further; and then they appear to recede to the north, leaving a broad flat for a mile below the foot of the rapids. On the south the bluffs leave the river's brink about 1,000 feet above the dam and follow along parallel with the bank, leaving a flat averaging 700 feet wide. This continues to about 1,500 feet above the foot of the rapids, where a headland juts out into the river. Opposite island No. 1 is a small valley coming down to the river, the channel of an entering creek.

The flats on each side of the river, and the numerous islands, give fine facilities for water-power improvement, the valley from bluff to bluff at the lower half of the rapids being about 3,500 feet wide.

FALL AND POWER.—With a head of 50 feet, the total theoretical horse-power, at an ordinary low-water stage, is 14,182 horse-power, or, with an efficiency of 75 per cent., 10,636 effective horse-power.

SHIP-CANAL.—Below the bridge which crosses island No. 1, 1,200 feet below the dam, there are 900 feet of frontage on the upper level of the ship-canal, with an average head of 16 feet. There is, of course, an immense number of sites below this on the ship-canal, but it is hardly probable that they will be used to any extent, because there are much better places elsewhere for taking the power, and also the requirements of navigation limit the amount of water that can be carried through the canal with its present size. The lots upon the upper level of the canal, however, will be, and are already used to a large extent. These lots are the property of the Green Bay and Mississippi Canal Company. The mills are: No. 1, paper, wood-pulp, and flour mills; No. 2, wood-pulp; No. 3, addition to No. 2, for the manufacture of artificial woodware; No. 4, planing-mill; No. 5, saw-mill; No. 6, hub and spoke factory.

Although no improvement of the water-power was undertaken on an extensive scale previous to 1880, there are two works of magnitude already finished. It is true that the sites are almost entirely vacant, but everything is ready for the setting of turbines sufficient to make Grand Kaukauna rapids the site of a large manufacturing town.

KAUKAUNA WATER-POWER COMPANY.—Several eastern capitalists, largely interested in the Milwaukee, Lake Shore and Western railroad, which first strikes the river at the south bank of Grand Kaukauna rapids, organized into an association called the Kaukauna Water-Power Company, and began improvements of a most extensive character on the south bank. The officers are: President, Joseph Vilas; vice-president, F. W. Rhinelander; general manager, H. G. H. Reed; treasurer, Charles Luling; engineer, James M. Barker.

The plan is to establish the car-shops of the railroad there, and to utilize the power in various kinds of manufacturing. A town, to be called Ledyard, has already been laid out, and the intention is to make it a great success. The locating of the shops there will immediately bring a considerable population. Starting above the dam, they have run a canal along the south bank, and intend to utilize the power along it. This power belongs to the third class, given under the title of the "Legal conditions of the Lower Fox water-powers", and the Green Bay and Mississippi Canal Company intend to bring suit, so soon as they take water from above the dam, to make them pay rent for it. Whatever be the decision, the improvement will undoubtedly remain.

The canal starts 400 feet above the dam, and for 400 feet it runs at an angle of about 45 degrees with the bank. When about 200 feet from the river it turns, and then runs nearly parallel with the south channel of the river for 2,000 feet, making a total length of 2,400 feet, and the lower fourth of its course is bent a few degrees away from the river. The greatest width is at the bulkheads, where it is 150 feet across. The smallest width is 86 feet; the depth, 11 feet. The total fall in the bed from the head-gates to the lower end is 2 feet, and the maximum velocity is calculated at 300 feet per minute. The area of flow at the bulkheads is 640 feet, and the depth 10 feet.

An embankment and a retaining-wall form the lower bank of the canal. This consists of a clay and gravelly earth embankment, held on the lower side by a vertical dry-masonry retaining-wall, with a flagstone coping. The sloping inner surface of this embankment is faced with laid stone, and the width on top is 20 feet. The inside slope is one to one, and the outside one to four. The retaining-wall is 3 feet wide on top, and the base averages 5 feet. The inside facing averages 18 inches thick, and there is a stone bulkhead at the upper end of the canal, about 150 feet from the head, for shutting off the water when repairs are necessary. The average head obtainable is 18 feet. The company has shut off the water from the south channel of the river by a dam, and intends using it for a tail-race, and, starting below the foot of the canal, has blasted a tail-race out of the limestone bed of the south channel, by which to make the available head of water nearly uniform along the canal. The closing of the south channel also gives more room. The company has a frontage along the canal, below the dam, of 1,900 feet, and at the end 200 feet additional. This would give 38 lots of 50 feet face each, and from 320 to 360 feet depth, down to the tail-race, beside four 50-foot lots facing the end of the canal.

The company claims the right to one-half the flow of the river, without interfering with navigation, and at the ordinary low-water flow of 2,500 cubic feet per second this would give, under 18 feet head, 2,553 theoretical horse-power.

About two-thirds of the way down the canal is a newly-erected wood-pulp mill, No. 8, which has leased 300 horse-power at $5 per horse-power per annum, and flumes were being built in the summer of 1881 at the extreme lower end of the canal for a cotton-mill, the first of its kind on the river.

The embankment will undoubtedly be used for a roadway, and we may be sure that the Milwaukee, Lake Shore and Western railroad will offer all the conveniences for shipping in its power. The main wagon-road leading over the river crosses the canal.

EDWARDS & MEADE POWER.—The remaining power improved since 1880, but not yet utilized, is the Edwards & Meade water-power. Captain N. M. Edwards lives in Appleton, and is the engineer of the Green Bay and Mississippi Canal Company. The owners have taken advantage of the channel branching off from the main north channel, between islands No. 1 and No. 2, and, forming it into a pocket by damming up the ends and sides, they intend to make use of the power at the lower end, where they control the land. This power comes under the fourth class mentioned in the section giving the legal conditions of the Lower Fox water-powers. This channel starts 600 feet below the bridge, and the dam is 1,000 feet below the head of the channel. The islands are low, and dikes run on each side almost the whole length of the channel. The pond averages about 200 feet wide, and at the broadest place is 275 feet across. The embankment along the south side is of earth, and the north side is bounded by a stone wall, built with limestone quarried right at hand.

Everything is done in a substantial manner. The stone wall is dry-laid rubble, with a straight batter on each side, and at every 3 or 4 feet distance on the inside is a string course of 3 or 4 inch oak plank, set into the masonry. To this is spiked plank facing. While building the wall openings were left for head-races to the mills. The dam at the end does not differ materially from the side wall.

The method of arranging the openings for flumes, so that they can be used, if required, without difficulty, is this: Heavy oak timbers and sills were built into the wall across the openings, and on these planks were spiked, flush with the inner face of the dam. When it is required to use the opening, the flume can be built up back of the planking, and then, when all is ready, the front timbers and planking can be cut away. Thus all necessity of coffer-dams around the opening while building the flume is avoided.

There is just below the head of the channel a bulkhead for shutting off the water similar to the one used on the Hyde & Harriman canal, at the lower level at Appleton. The head at the foot of the channel is 16 feet, and there is room for five 50-foot lots at the end of the pocket, and for eight or more on each side. There are also openings left at the end for extending large flumes down from the dam, by which 20 feet head can be obtained. The bed of the channel between islands No. 2 and No. 5, and also of that between islands No. 5 and No. 1, will make excellent tail-races. This power is estimated by Captain Edwards to be equivalent to from 1,200 to 1,500 horse-power, requiring, with 16 feet head, a volume of 826 cubic feet per second. A wood-pulp mill, No. 7, was erected in the winter of 1880–'81 at the lower end of the pocket, with a capacity of 2,200 pounds of dry pulp per twenty-four hours.

PROPOSED IMPROVEMENTS.—There are several improvements that have been proposed for utilizing the flow over the remaining fall of the river. The map illustrates these. It is perfectly feasible to build a dam across the main channel from island No. 2, starting 650 feet below its head, and from it run a canal along the north bank of the river. This would catch all the flow of the river except what was used from the Kaukauna water-power canal and the Edwards & Meade power. A head could be obtained by extending the canal about 800 feet down, varying from 10 feet at the head to 20 feet at the foot, but could be made nearly 20 feet all the way by excavating a tail-race, and mills could be stationed along the dam itself, as well as on the canal.

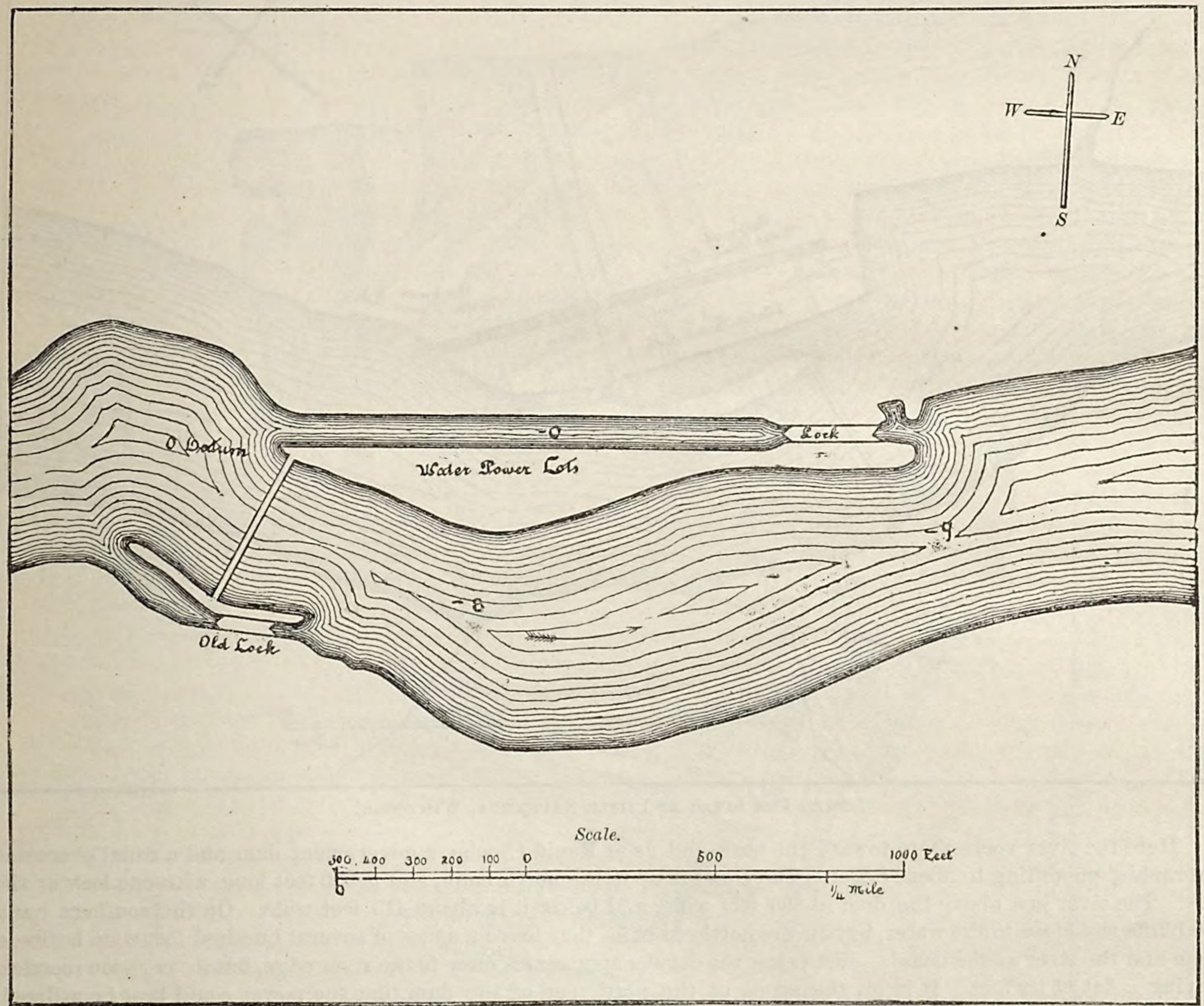
The map also shows a practicable scheme of damming up the channel between islands No. 1 and No. 3 by wing-dams, forming a pocket with the same level as the tail-race of the Kaukauna Water-Power Company's canal. A head of 18 feet could then be obtained, and mills, etc., would be stationed along the lower part of the pocket. If the south channel is shut off permanently, this power would only get the discharge from the Kaukauna Water-Power Company's canal, and this plan would require about 2,600 feet of dam, wing-dam, and dike. Tail-races should be blasted out on each side, and that on the north would also serve for a portion of the Edwards & Meade power.

We have now discussed plans for using the upper 36 feet of the fall; there remains yet 14 feet. About 800 feet below the foot of island No. 5 the river bends again to the northeast, as it flowed above Grand Kaukauna, and the rapids end just below this bend. The river is 1,600 feet wide at the bend; but below a bay projects into the south bank, and the river is there 2,200 feet wide. The bed of the river is limestone, as all along the rapids, and it is suggested by Captain Edwards to build a dam across the river where it is 1,600 feet wide. Starting from the south bank, he would run it directly across until within 200 feet of the north bank, then up the stream for about 1,000 feet, until it merged into the level of the north bank. This dam and dike would be 2,400 feet long, and the head available would be 14 feet, and it would catch the whole flow of the river. Captain Edwards' idea is to station mills, built over the river, all along the face of the dam; to make a roadway of the crest of the dam, and to run railroad tracks back and forth over the river on trestles or cribs, as at Appleton. A waterway and waste-weir of about 300 feet width would be left in the middle of the channel, which, for a river of so slight rise, seems sufficient to control the level. There would be 1,100 feet of facing on the main dam, and at least 800 feet on the wing-dam along the north shore, and it would be necessary to blast out a tail-race for mills along the latter. The theoretical

power of this improvement at ordinary low-water and 14 feet head would be 3,971 horse-power, and this would be sufficient to supply 104 horse-power for every 50 feet of available space along the dam and wing-dam at an ordinary low stage of the river.

THE RIVER FROM GRAND KAUKAUNA DOWN TO RAPID CROCHE.

From the foot of the canal the course is north-northeast for a distance of 2 miles, and then for 1.3 miles the river runs northeast to the Rapid Croche dam. The river below the Grand Kaukauna rapids is from 1,200 to 2,200 feet wide for nearly 2 miles, but it gradually contracts so as to average about 500 feet wide for the lower half of the distance down to Rapid Croche, and in places it is not more than 400 feet wide. Below the foot of the Grand Kaukauna canal the bluffs rise from the water direct, and, with trifling exceptions, they continue thus, well wooded, down to Rapid Croche. Navigation is by slack water from the Rapid Croche dam up to the Grand Kaukauna canal.



LOWER FOX RIVER AT RAPID CROCHE, WISCONSIN.

RAPID CROCHE.

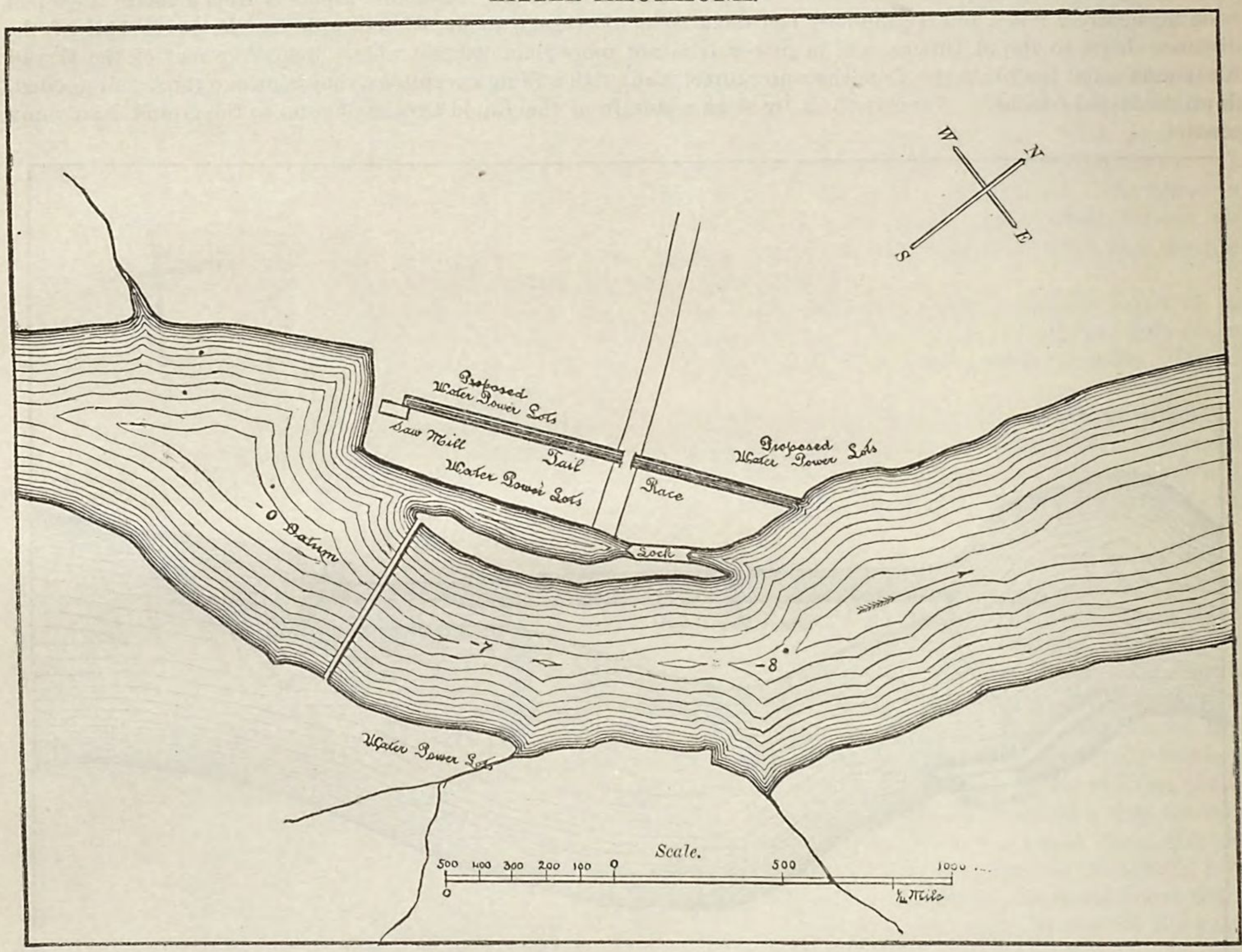
The river here runs east. The government has built a dam 4½ miles below the Grand Kaukauna dam, and by a canal 1,760 feet long on the north bank floats the boats past the rapids of about 9 feet fall to the slack water of the Little Kaukauna dam. The river just above the Rapid Croche dam is 640 feet, and below 440 feet wide, and the bluffs come down on each side close to the river, except that between the ship-canal and the bank of the stream is a space about 900 feet long, and varying from a few feet wide at the ends to 200 feet at the middle part. This ground is owned by the Green Bay and Mississippi Canal Company, and is the proper place for utilizing the power at this locality.

FALL AND POWER.—The head available is 8 feet, and the theoretical power at ordinary low water is 2,269 horse-power; but none of this power is used. There is an old lock at the north end of the dam which was formerly used for navigation, and there could easily be a side-track laid from the railroad to the water-power.

THE RIVER FROM RAPID CROCHE DOWN TO LITTLE KAUKAUNA.

In this distance of 6 miles the general course is northeast, and the river is not so winding as in its upper part, the bluffs forming the immediate banks of the river almost the whole distance. A peculiar feature of this stretch is the narrowness of the river, below Wrightstown, which is about one-third of the way down, the average width being about 450 feet, while in many places the banks are scarcely over 300 feet apart.

LITTLE KAUKAUNA.



LOWER FOX RIVER AT LITTLE KAUKAUNA, WISCONSIN.

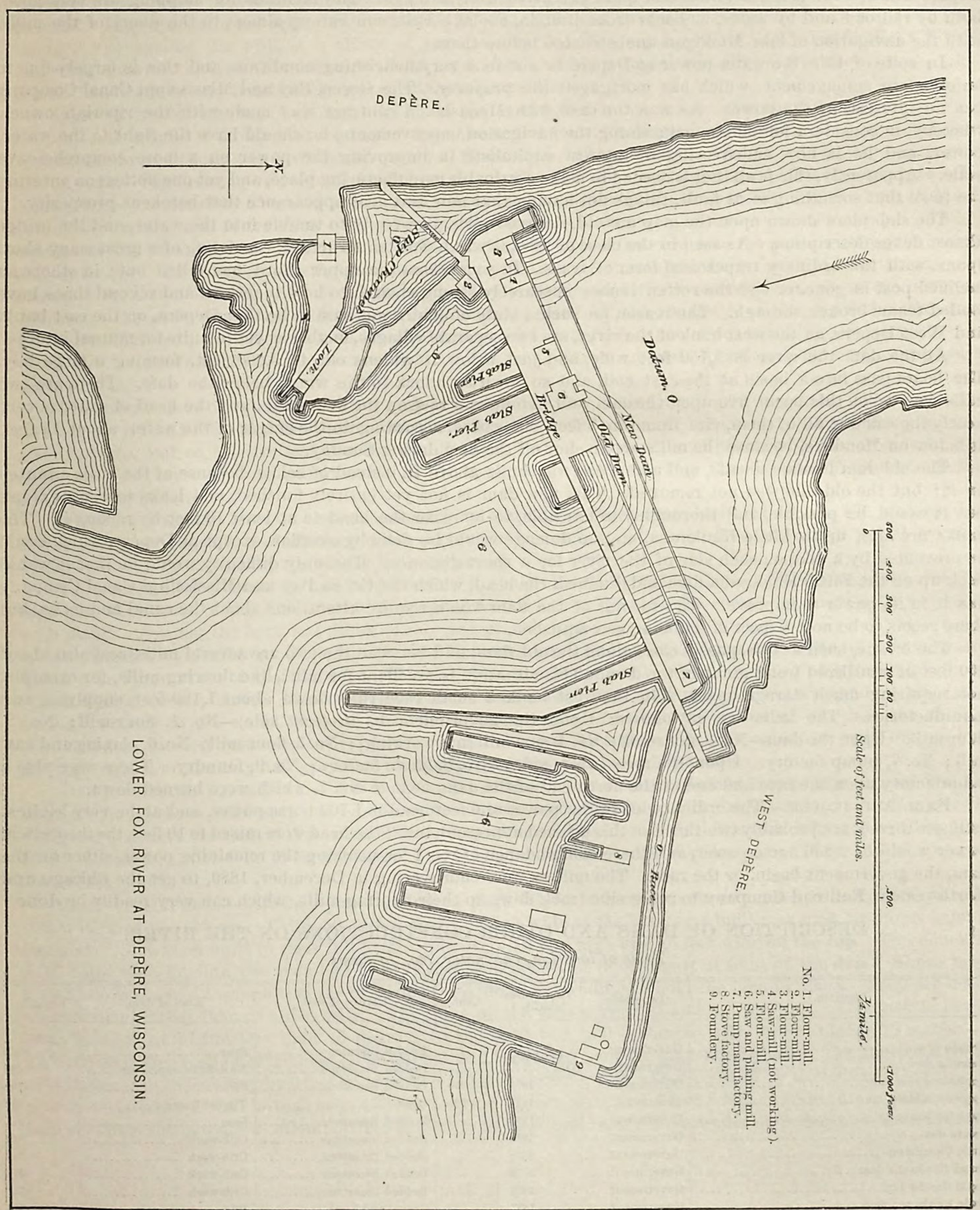
Here the river veers more toward the east, and as at Rapid Croche, a government dam and a canal overcome the rapids, amounting to about 8 feet. The canal is upon the north bank, and is 950 feet long, with one lock at the foot. The river just above the dam is 800 feet wide, and below it is about 475 feet wide. On the southern bank the bluffs rise close to the water, but on the northern bank they leave a space of several hundred feet wide between them and the river at the canal. Just below the canal a spur comes close to the river edge, but it very soon recedes, leaving a flat at its foot. It is on the space at the north end of the dam that the power could best be utilized. There is a saw-mill there now, facing the pond. With a tail-race running up the middle of the flat, there would be 1,100 feet of frontage along the ship-canal available for manufactories, with an average head of about 7½ feet. A canal could be run along the bluff back of the ship-canal, and mills be built along it, using the tail-race mentioned so far as it extended, and then discharging into the river. There would be at least 2,000 feet of available frontage, on it. There is also a chance for running a canal above the south bank and getting about 1,000 feet of frontage upon it.

FALL AND POWER.—Thus abundance of space would be provided for utilizing the total power of the river, which, at 7½ feet head and ordinary low-water flow, would be 2,127 theoretical horse-power, or, with an efficiency of 75 per cent., 1,595 effective horse-power. The Green Bay and Mississippi Canal Company owns only the land between the ship-canal and the river; the rest is in the possession of various persons.

The locality is not considered by those qualified to judge very accessible to railroads, but it is possible to reach it.

THE RIVER FROM LITTLE KAUKAUNA DOWN TO DEPÈRE.

The river flows with hardly a bend nearly northeast for this distance of 6 miles. Along the upper portion of this section it is from 1,500 to 2,000 feet wide, but in the lower half it averages 800 to 1,000 feet across, and except just at Little Kaukauna the bluffs skirt the edge of the river on each side down to Depère. Along the upper 3 miles there is considerable timber on the bluffs.



LOWER FOX RIVER AT DEPÈRE, WISCONSIN.

DEPÈRE.

This town is an old place, and, as its name indicates, is of French origin. Although 7 miles above the mouth of the river, at the head of Green bay, the navigation on the level of lake Michigan extends to this town, where there is a government dam with a lock, the last on the river. The stream suddenly turns at Depère, and runs a little west of north for a few thousand feet; then it bends to the northeast and continues without change to Green bay. At Depère are several manufactories and quite extensive iron furnaces. The facilities for shipping are very good, both by railroad and by water, as boats from Buffalo, on lake Erie, can run up almost to the doors of the mills, with the navigation of lake Michigan unobstructed before them.

In spite of this the water-power at Depère is not in a very flourishing condition, and this is largely due to unfortunate management, which has mortgaged the property. The Green Bay and Mississippi Canal Company has no interest in the power. As was the case with Menasha, a contract was made with the riparian owner, whereby, in consideration of his maintaining the navigation improvements, he should have the right to the water-power, and he is now endeavoring to interest capitalists in improving the power on a more comprehensive scale. Apparently, this is all that is needed to make a valuable manufacturing place, and yet one notices on entering the town that something is at fault, things not having that new and neat appearance that betokens prosperity.

The slab piers shown upon the map are old, decayed piles, just ready to tumble into the water, and the bridge almost defies description. As seen in the close of 1880, it was a wooden structure, consisting of a great many short spans, with the ordinary trapezoidal form of truss. In some cases the upper chord has fallen out; in others an inclined post is gone, or else the rotten timber is scarcely strong enough to hold together, and several times have loaded teams broken through. The reason for such a state of affairs was said to be that Depère, on the east bank, and West Depère, on the west bank of the river, are two separate villages, unable as yet to unite for mutual interest.

At the dam the river is 1,750 feet wide, and just below it widens out to 3,000 feet, forming a large bay. The boats pass into a basin at the east end, and so down by a lock to the water below the dam. There are two mills situated on this basin, five upon the dam, and two upon a race on the west bank, and the head of water is very nearly the same at all of them, viz: from 6 to 7 feet, but varies, according to the stages of the water, about 1½ feet. It is low on Mondays, because the mills above shut off the flow during Sunday.

The old dam became unsafe, and a new one was built above it, instead of below, because of the mills situated on it; but the old one was not removed. This new dam is not yet entirely finished, and leaks to some extent, but it would be possible, and thoroughly practicable, to increase the head to at least 10 feet by raising it. The banks are high up to Little Kaukauna, and no damage would be done by overflow except at Depère, which could be prevented by a dike on each side of the river for a short distance. The only difficulty would be that it would back up on the Little Kaukauna dam and diminish the head, which the Green Bay and Mississippi Canal Company has it in its power to improve. The raising of the dam would require alterations about the canal and locks, but there seems to be no prospect of its being accomplished.

The bridge, such as it is, passes close along the old dam, and between the two are several mills, and also about 900 feet of unutilized frontage upon the dam. This situation is excellent for mills, like flouring-mills, for example, not requiring much storage space. On the west bank a small race runs down about 1,100 feet, supplying two manufactories. The mills are as follows: Upon the government basin (east side)—No. 1, flour-mill; No. 2, flour-mill. Upon the dam—No. 3, flour-mill; No. 4, saw-mill (not working); No. 5, flour-mill; No. 6, planing and saw mill; No. 7, pump factory. Upon the race (west side)—No. 8, stave factory; No. 9, foundry. There were also a manufactory upon the race and one at the north end of the dam, next to No. 7, which were burned down.

FALL AND POWER.—The ordinary low-water power at 6 feet head is 1,702 horse-power, and at the very highest estimate there is not probably two-thirds of this utilized at present, but if the head were raised to 10 feet, the theoretical power would be 2,836 horse-power, and there is abundance of room for utilizing the remaining power, either on the dam, the government basin, or the race. The millers were endeavoring in December, 1880, to get the Chicago and Northwestern Railroad Company to run a side-track down to their flouring-mills, which can very readily be done.

DESCRIPTION OF DAMS AND OTHER CONSTRUCTIONS ON THE RIVER.

Table of location, character, etc., of dams.

Location.	Ownership.	Time when built.	Cost.	Nature of bed.	Kind of dam.	Length.
						Feet.
Neenah dam	Government			Bedded limestone	Spar	*775
Menasha dam	Government	Old		Bedded limestone	No definite character	*480
Appleton upper dam	Government	1875	$40,000	Bedded limestone	Stone	700
Appleton middle dam	Private	1877	9,500	Gravel	Timber frame	450
Appleton lower dam	Government	1855		Bedded limestone	Spar	417
Cedars dam	Government	1878		Bedded limestone	Crib-work	810
Little Chute dam	Government	1878		Bedded limestone	Crib-work	715
Grand Kaukauna dam	Government	1878		Bedded limestone	Crib-work	613
Rapid Croche dam	Government	1878		Bedded limestone	Crib-work	525
Little Kaukauna dam	Government	1877		Gravel and bowlders	Pile	586
Depère dam	Government	1879	30,000	Bedded limestone	Crib-work	1,305

* Approximate.

STONE PIER AT APPLETON.—In addition to these is the fine stone pier or revetment wall 800 feet long, and averaging 18 feet in height, at the upper level at Appleton, built in 1880 upon the limestone layers forming the bed of the stream. Constructed of solid masonry throughout, the exterior is laid in regular courses of dressed stone, 1 foot thick. The inner face is vertical, but the outer one inclines. It is 6½ feet wide on the top, has an 11-foot base where 18 feet high, and the coping stones are doweled fast for the first 36 feet from the dam, where exposed to ice. There are ten openings, some 15 by 17¼ feet high, others 13½ by 6 feet, for supplying water to mills. They are set in the upper half of the height of the wall, and have a segmental arched roof. At the back, rising 8 feet against the wall, is a filling of gravel or earth. The coping stones, etc., were brought from the limestone quarries at Great Kaukauna or Duck creek, but are only a superior quality of the rock found right at hand. The work is very handsomely and substantially executed.

DAM AT UPPER LEVEL, APPLETON.—This is by far the finest dam on the stream and in that part of the country. It is built of the limestone quarried from the bed of the river at the spot, except the coping stones, which which were brought from the government quarry at Kaukauna. The masonry is dressed rubble; the coping stones ashler work. The drawing on page 46 (made from description and dimensions given) explains the structure. Each coping stone is fastened by a band of 1-inch round iron to a hook set into the masonry at the toe of the dam. Adjoining coping stones are also fastened to each other by iron straps 1¼ inches wide, doweled into the stone. The lower courses of the masonry are bolted to the rock-bed, and the irons are fastened into the stone with an alloy of lead and antimony. In building, a coffer-dam was first erected, so as to confine the river to the north side of the channel; then the bed was cut smooth to receive the masonry, and the dam completed up to the coffer-dam. Afterward the coffer-dam was removed, and the process repeated for the remainder of the way across the stream. The coffer-dam was principally made of triangular sets, with string-pieces, on which planking was spiked.

DAMS AT LOWER LEVEL, APPLETON, AND AT NEENAH.—These are each spar-dams, and one description will serve for both.

The lower dam at Appleton is built of spars or tree trunks 40 feet long, resting on log cribs. These cribs are 16 feet long by 8 feet wide and 8 feet apart, with their length in the direction of the current. Along these cribs rests a string-piece, and on this are laid the butts of the spars, which run back until they strike the river bed. Upon these spars is a layer of earth and gravel, and the space is open below. This form of dam is found to be tight, and works satisfactorily.

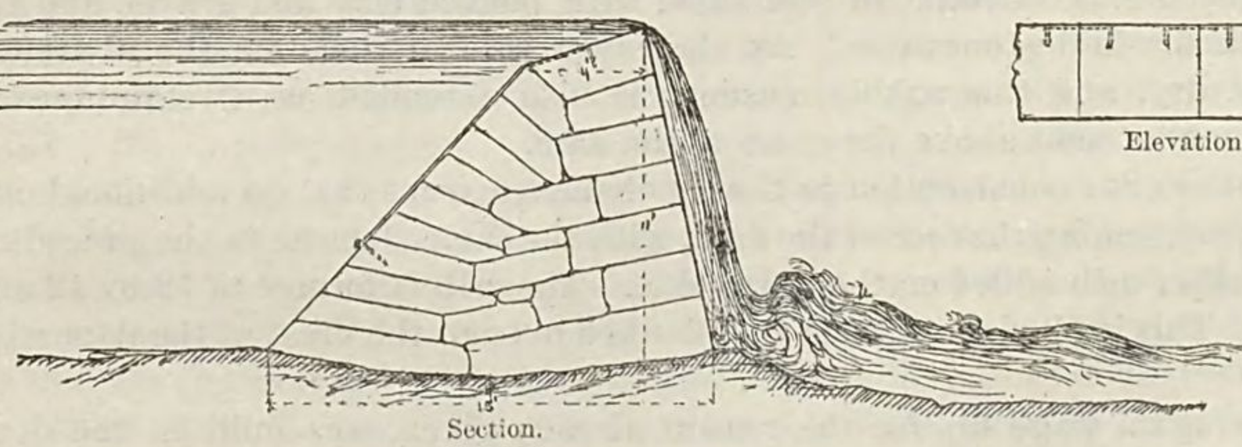
DAMS AT CEDARS, LITTLE CHUTE, AND RAPID CROCHE.—These dams are all built on the plan shown in the drawing on page 47, a continuous crib-work extending across the river. The lower and upper courses of stringers are 12 by 12 inches; the others 10 by 10 inches.

This crib is filled with stone, and is also bolted to the bed-rock by 1½-inch bolts. The timbers also are bolted together. The back of the dam, instead of sloping to the bed of the river, is cut off by a vertical back, sheeted with plank. Against the back is a filling of clay and gravel, with a slope of one to one to the river bed. The face is not protected by planking. The timbers, 6 by 10 inches, are 2 feet apart, and the spaces are filled in with stone. There is no apron at the face of the dam. The abutment consists of a crib-work core, into which the main crib-work of the dam is securely built. This crib-work core is surrounded and filled with packed clay and gravel, and the surface, sloping to the water, is faced with dry-laid stonework. At the lower side of the dam the abutment terminates in dressed rubble masonry, laid dry, and this rubble masonry is also extended as a retaining-wall for that portion of the clay and gravel of the abutment above the crest of the dam.

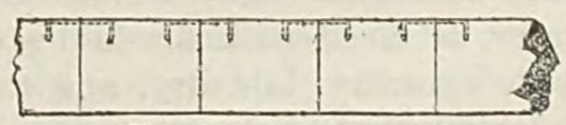
DAM AT GRAND KAUKAUNA.—This is of similar construction to that at Cedars, except that an additional crib 12 feet wide has been built on the lower side, continuing the face of the dam, with the same slope as in the preceding case, and is merely the Cedars dam with another crib added on the lower side. The crib is formed of 12 by 12 and 10 by 12 stringers, with 8 by 10 cross-pieces. This is filled with stone and planked over to the crest of the dam with 3 or 4 inch plank.

DAM AT DEPÈRE.—This dam (see drawing on page 48), for the reason already given, was built in the deep water back of the old one. Cribs 50 feet long by 28 feet wide at the base were built and sunk by stone, adjoining each other, and when built to their full height they were 12 feet high and 16 feet wide on the top. Three-inch iron drift-bolts were let into the rock-bed 12 to 18 inches at spaces of 8 feet apart in front of the dam. These project 1 foot above the bed through timbers extended from the cribs, tending to hold the dam in place. They are used as a precaution, rather than as a necessity. The front of the dam is vertical and not sheeted. The back is inclined from the crest at a little less than 45 degrees to the river bed, and is sheeted with 4-inch planks 12 inches wide. The upper surface is slightly inclined down stream, and is covered with the same-sized plank. The abutment consists of a timber crib 48 feet long by 9 feet wide of 12 by 12 inch timbers, with a flooring of 12 by 12 timber. On this is laid a trapezoidal-shaped wall of masonry, 47½ feet long by 6¼ feet high, and 5 feet 8 inches wide on top. The old dam still standing, the new one is often entirely hidden from view, and is, of course, under no hydrostatic pressure as yet.

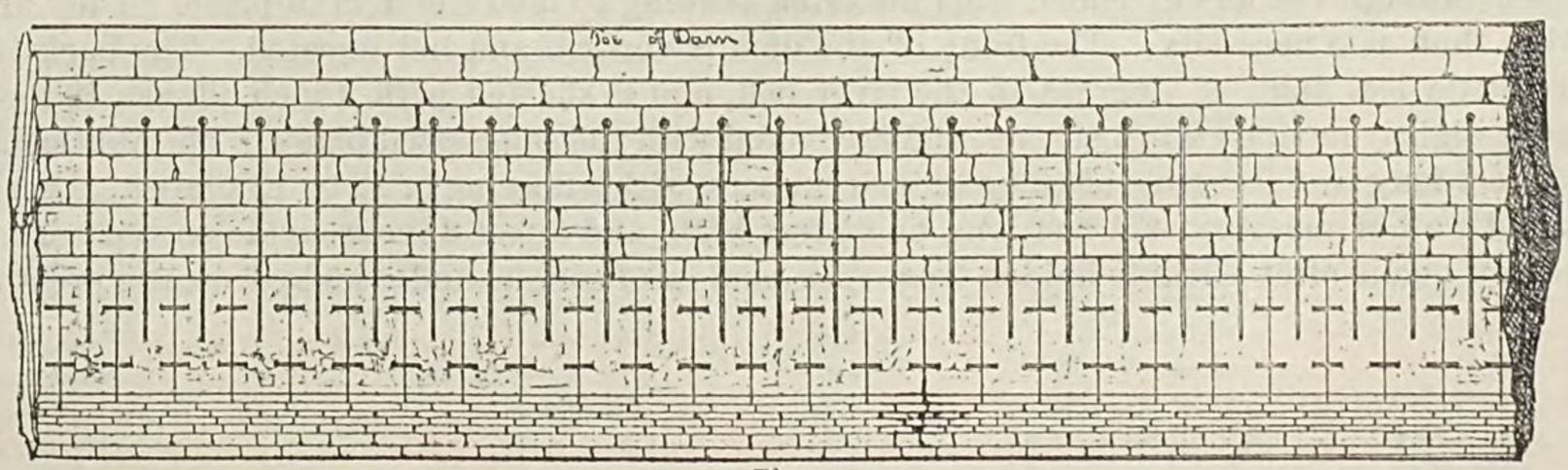
APPLETON, WISCONSIN: VIEW OF UPPER DAM, IN PROCESS OF CONSTRUCTION.



Section.

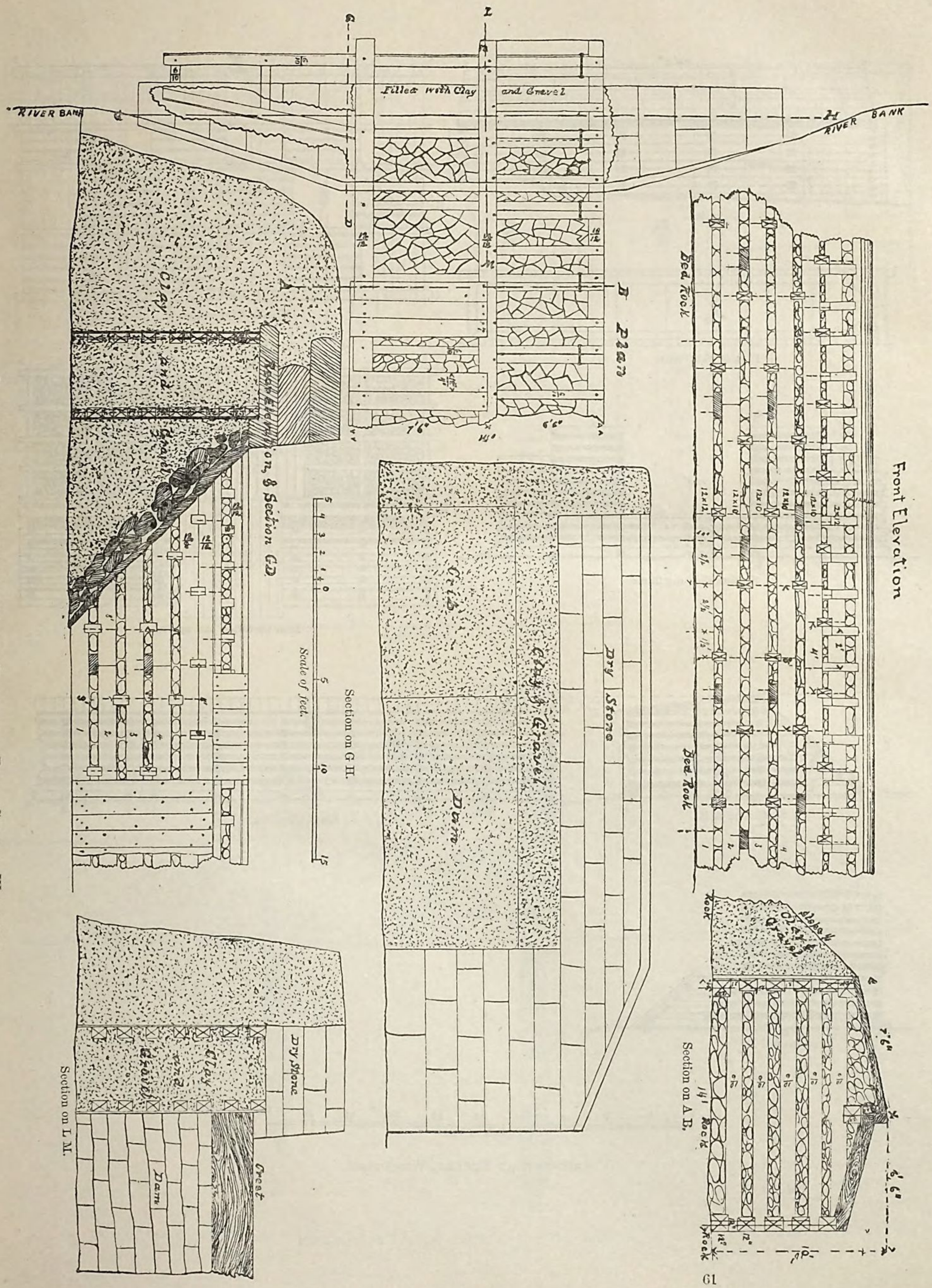


Elevation of coping stones.

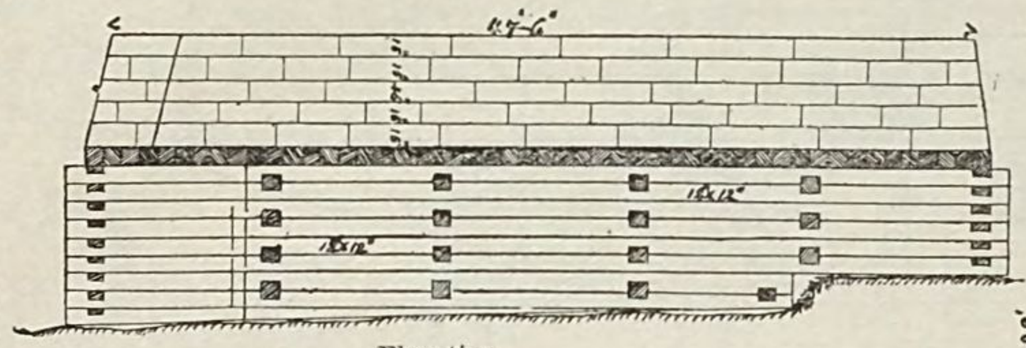


Plan.

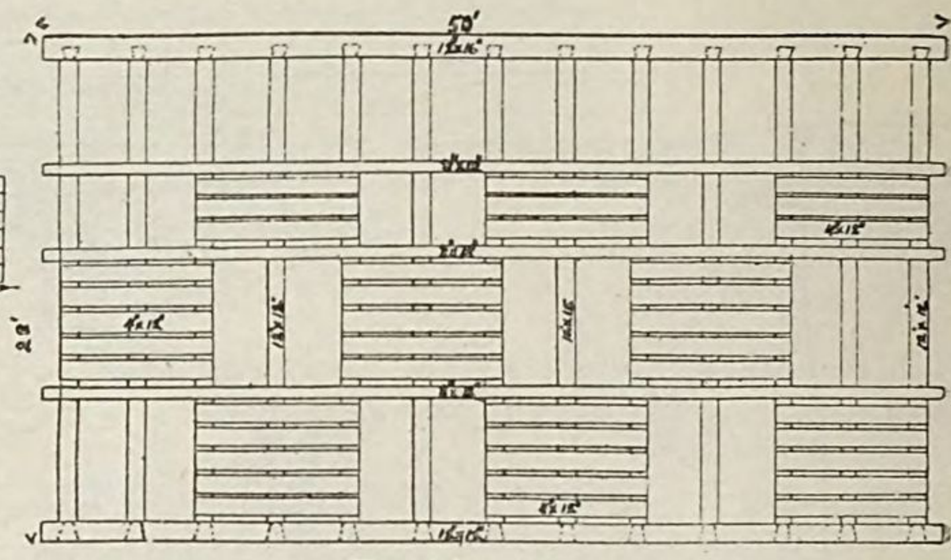
DAM AT UPPER LEVEL, APPLETON, WISCONSIN (drawn from description and dimensions given by the United States engineer corps).



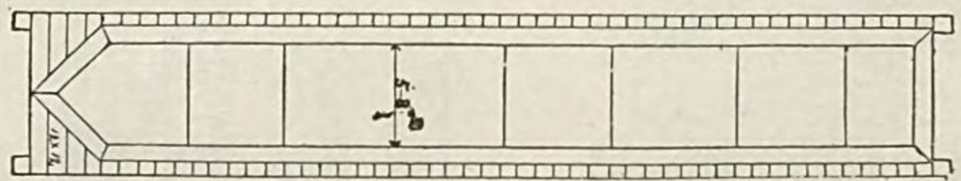
PLAN OF CRIB-DAM AT CEDARS, LITTLE CHUTE, AND RAPID CROCHE, WISCONSIN.



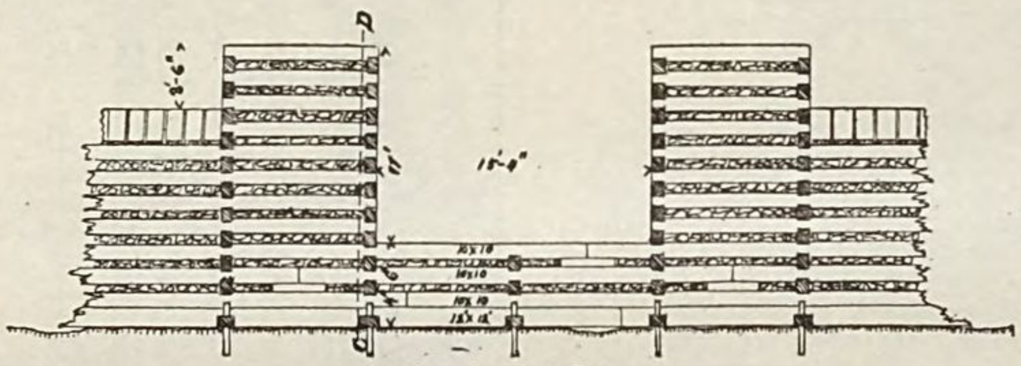
Elevation.



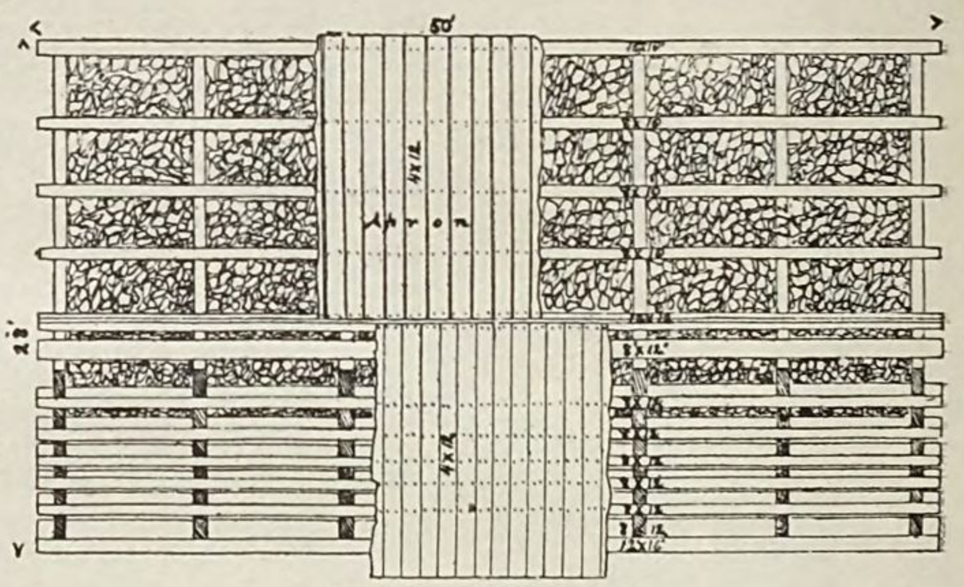
Plan of first course.



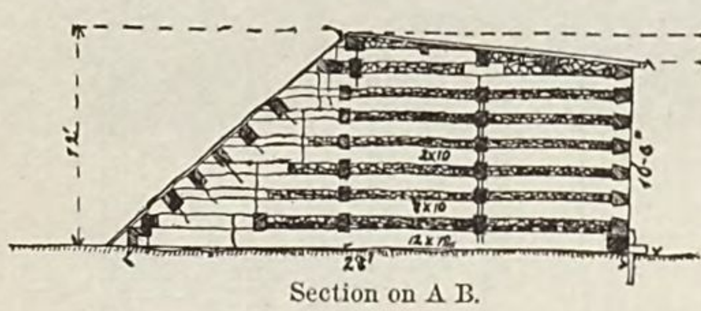
Plan of abutment.



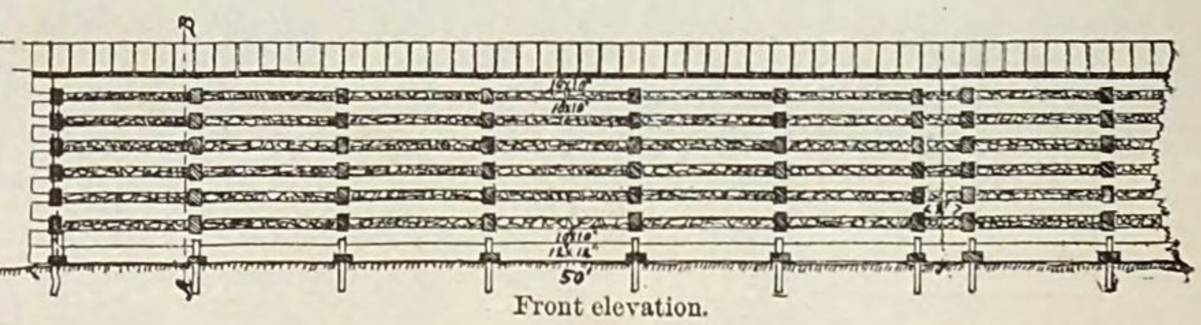
Section showing flume.



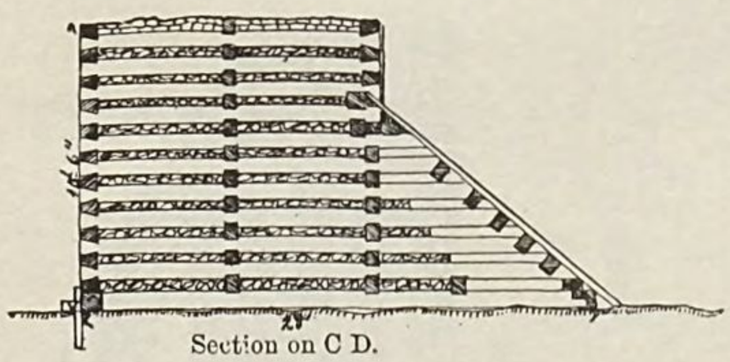
Rear elevation and apron.



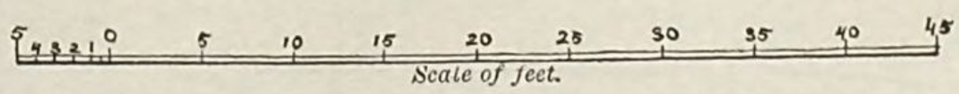
Section on A B.



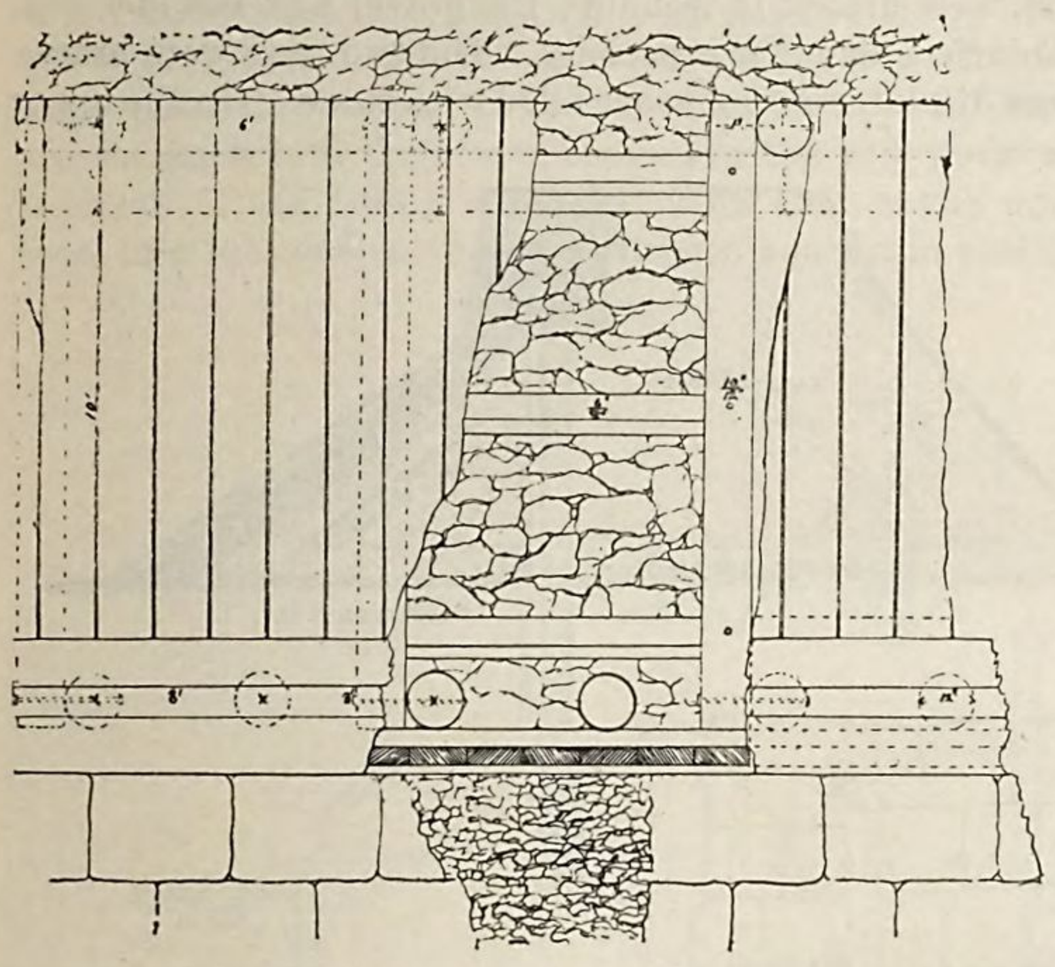
Front elevation.



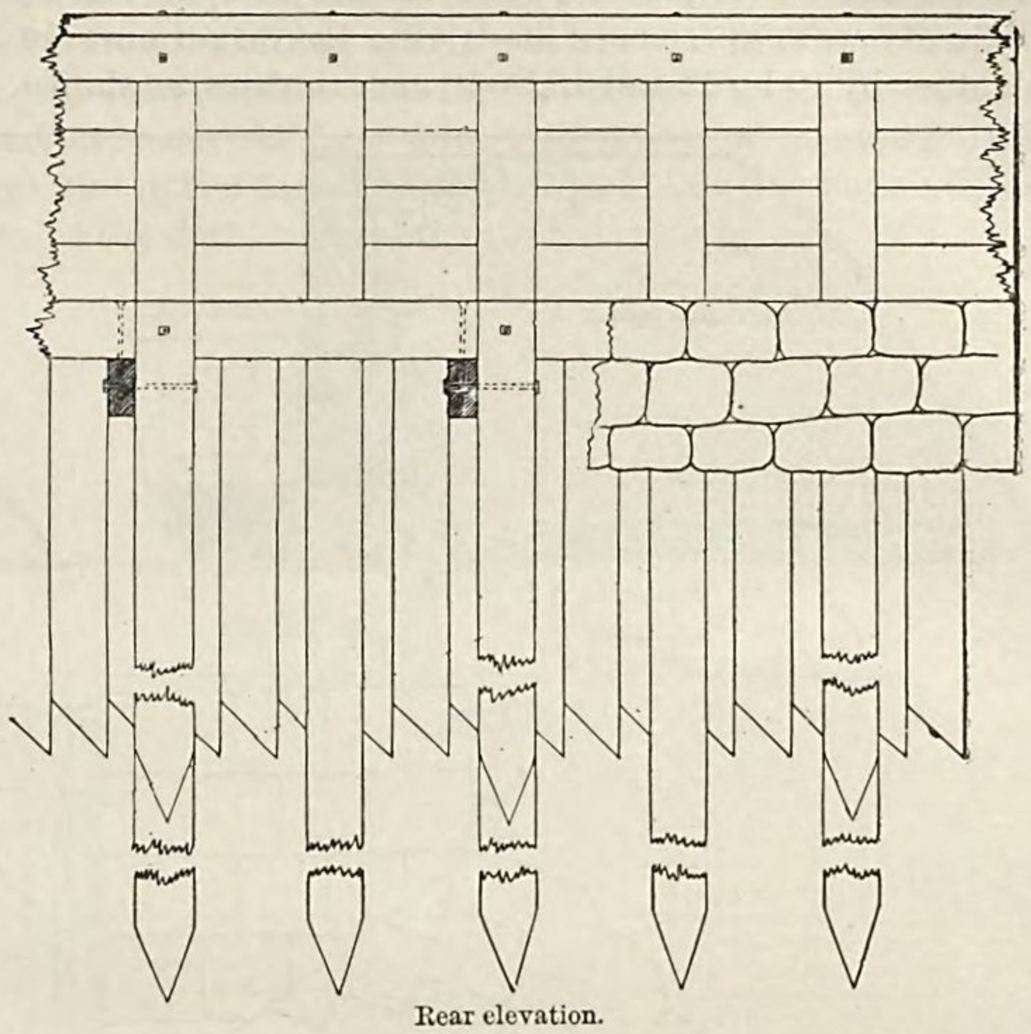
Section on C D.



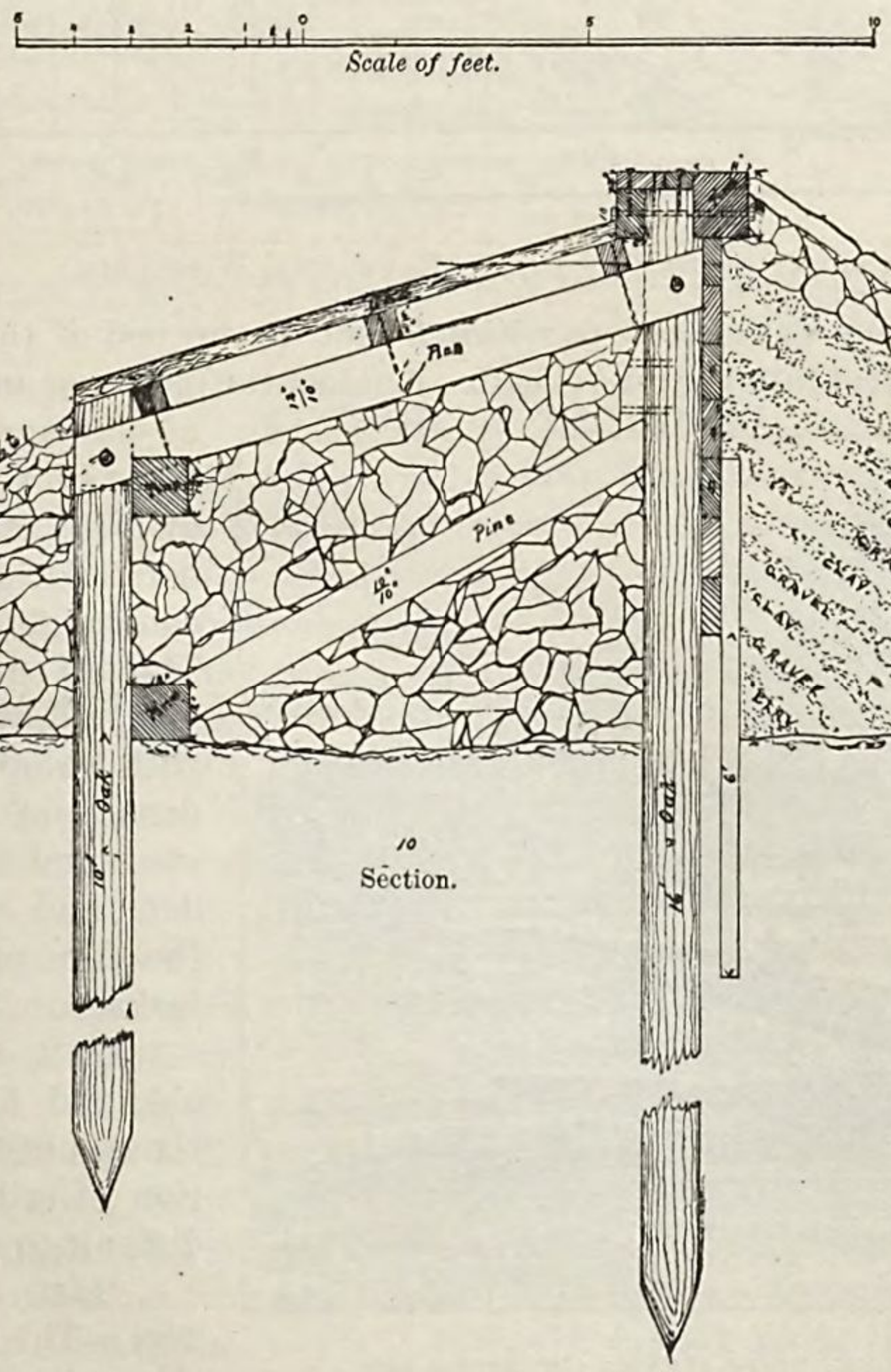
CRIB-DAM AT DEPÈRE, WISCONSIN.



Plan.

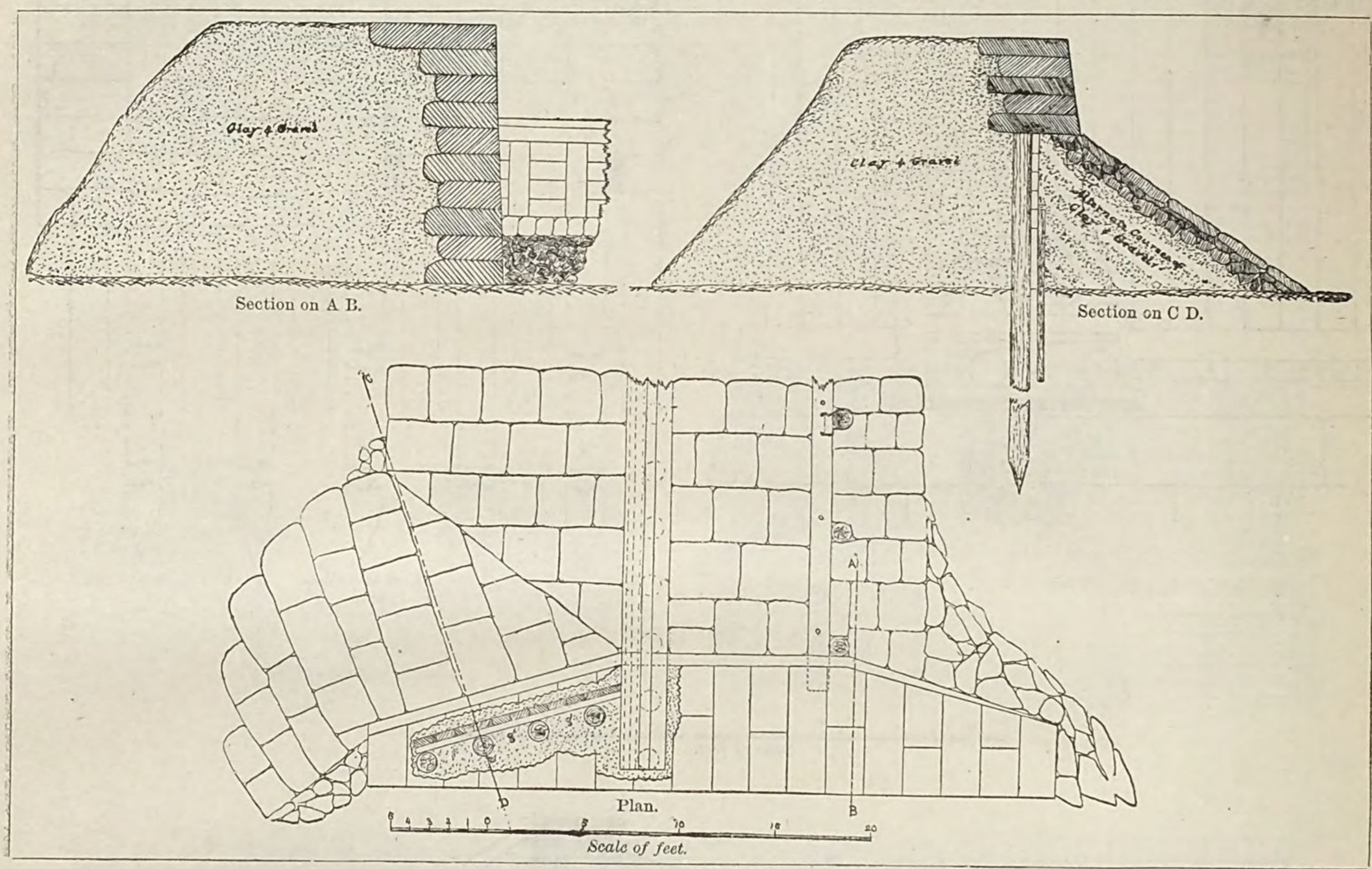


Rear elevation.



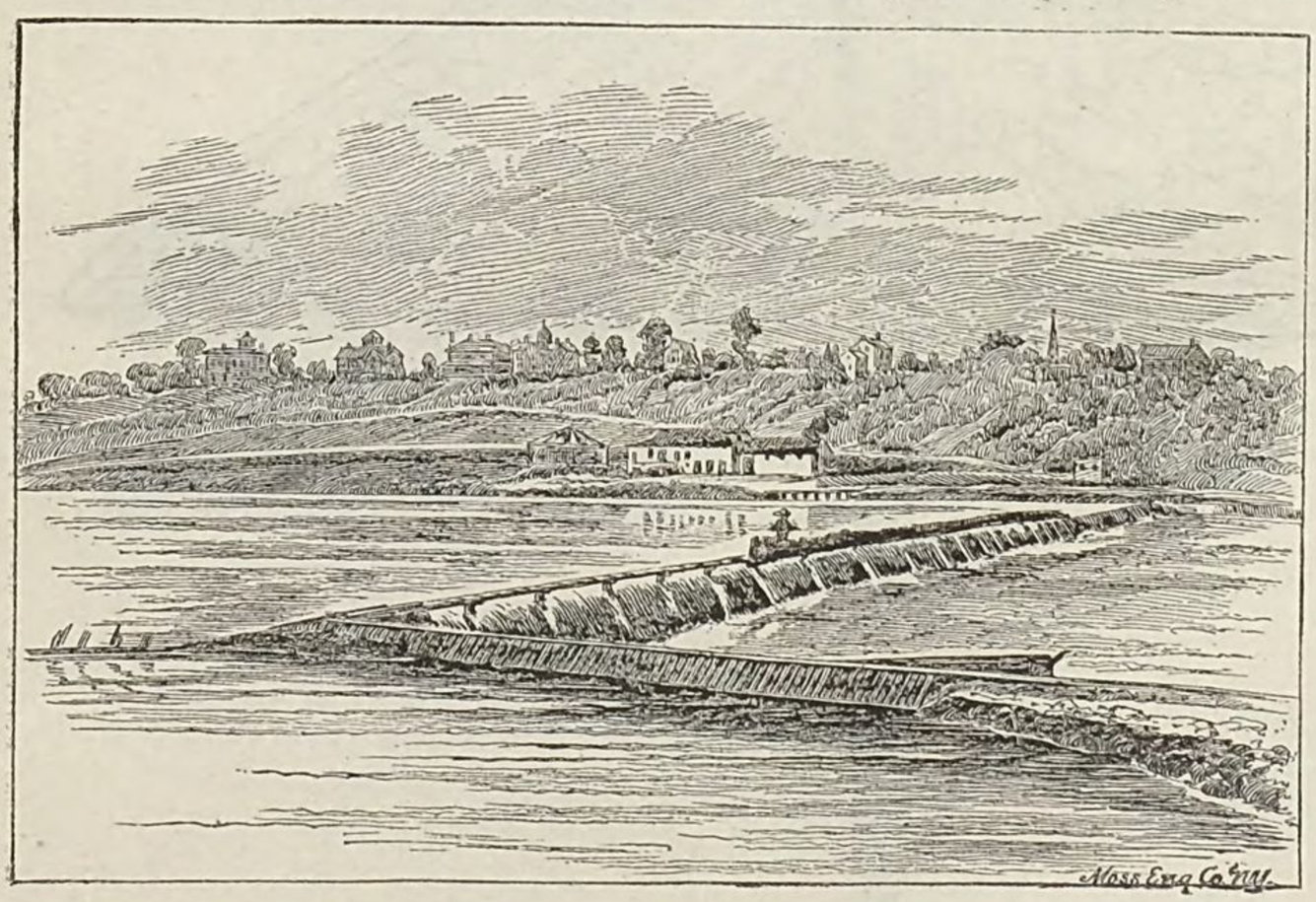
PILE-DAM AT LITTLE KAUKAUNA, WISCONSIN.

DAM AT LITTLE KAUKAUNA.—This is the only government dam on the river without a solid rock foundation (see the table on page 44); hence its construction is peculiar. The dam, of pile construction, was built below the old one. Two parallel rows of oak piles, 10 feet apart, were driven 14 feet into the gravel and bowlder bed. Difficulty was experienced in driving the larger ones, of 15 inches diameter especially. The two rows were braced together by 10 by 12 and 10 by 10 inch timbers, as shown, and the intervening space filled with stone. On the upper



ABUTMENT OF DAM AT LITTLE KAUKAUNA, WISCONSIN.

sides of the upper row 4-inch planking was spiked to within 2 feet of the bed of the river; then sheet-piling was driven down against this planking 4 feet into the gravel bed. Against the planking and sheet-piling alternate layers of clay and gravel were packed, with a slope of 1½ to 1; then a layer of 1½ feet of loose stone, and on this a course of carefully laid flat stones, 4 inches thick, coming flush with the crest of the dam. The top surface was planked with 4-inch oak, and at the face stones were filled in, with a slope of 1½ to 1. The abutment is formed of clay and gravel, faced with stone and a line of sheet-piling above the dam, and connecting with the piling of the dam proper, to prevent any possible leakage.



MIDDLE DAM AT APPLETON, WISCONSIN, FROM GRAND CHUTE ISLAND.

DAM AT MENASHA.—This dam is old, and has been patched at various times, until it consists of a conglomeration of cribs, spars, brush, gravel, etc., difficult to describe.

DAM AT MIDDLE LEVEL, APPLETON.—This is the only dam across the river that is not owned by the United States, and was constructed by Captain N. M. Edwards, of Appleton. Like the Little Kaukauna dam, it is on a gravel foundation, which the rapids have not succeeded in washing away, but it is a frame instead of a pile-dam.

The frame proper is a continuous crib-work, triangular cross-section, with a 16-foot base and 9 feet high. The face is vertical, and the back slopes to the river bed. The timbers are 10 by 12 inches, except at the toe, where they are 12 by 14 inches, to withstand better the greater pressure of the water. The crib-work is filled in with stone, and the back is covered with 4-inch planking, projecting at the toe over the ends of a line of sheet-piling driven 4 feet into the bed of the stream. The face is not covered, but is left open to the stone filling, which was allowed to take its natural slope when thrown in. Below the dam an apron 16 feet wide was built out on the bed of the river. Its timbers are set back into the lower courses of the crib-work, and are covered by a 4-inch thickness of planking. The tendency of the falling water is to work out a cavity under the apron for several feet back, but this action ceases soon, and the construction of the apron holds it in position to the dam.

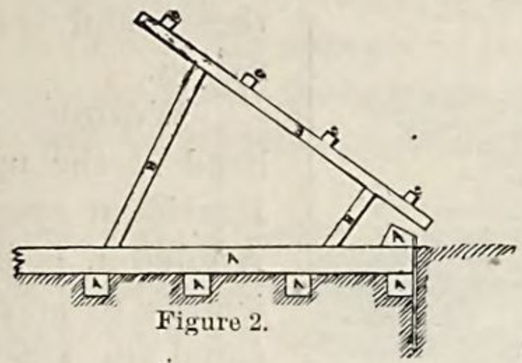


Figure 2.

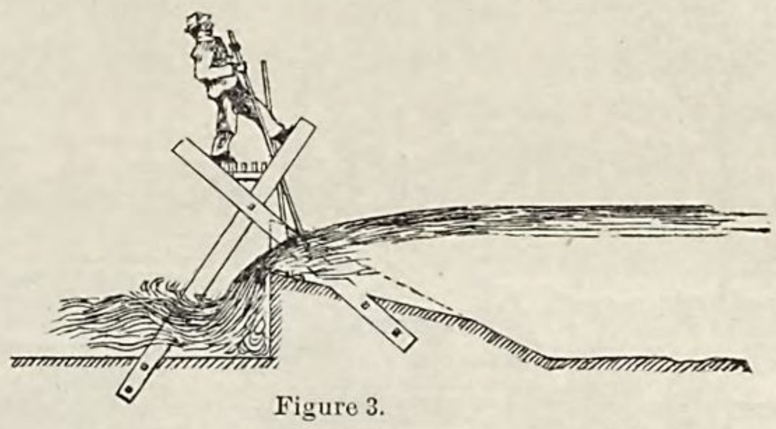


Figure 3.

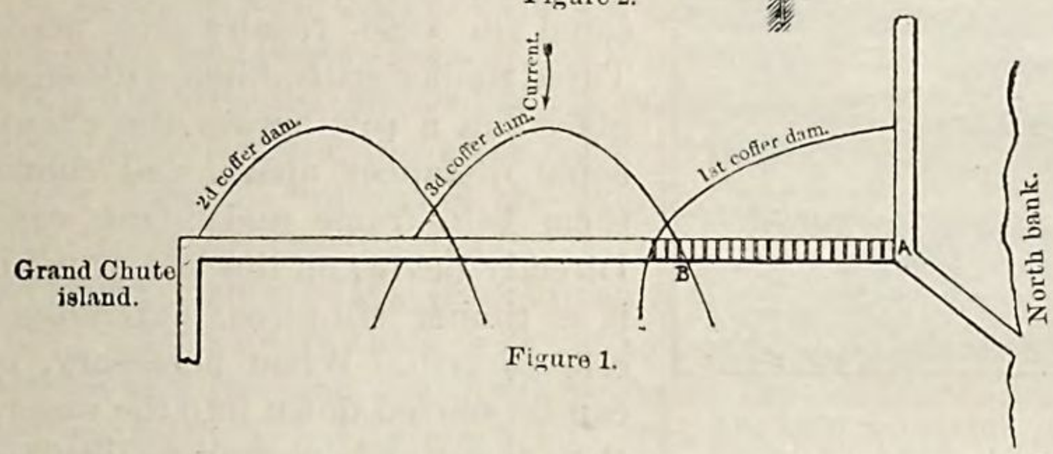
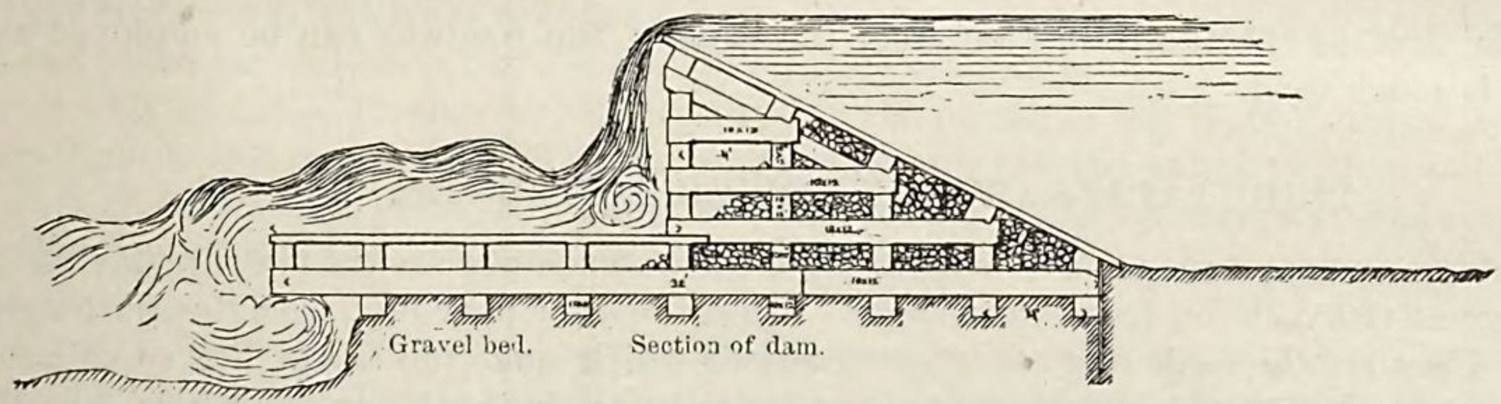


Figure 1.



DAM AT MIDDLE LEVEL, APPLETON, WISCONSIN (drawn from description and dimensions given by the engineer of the work, Captain N. M. Edwards).

METHOD OF BUILDING.

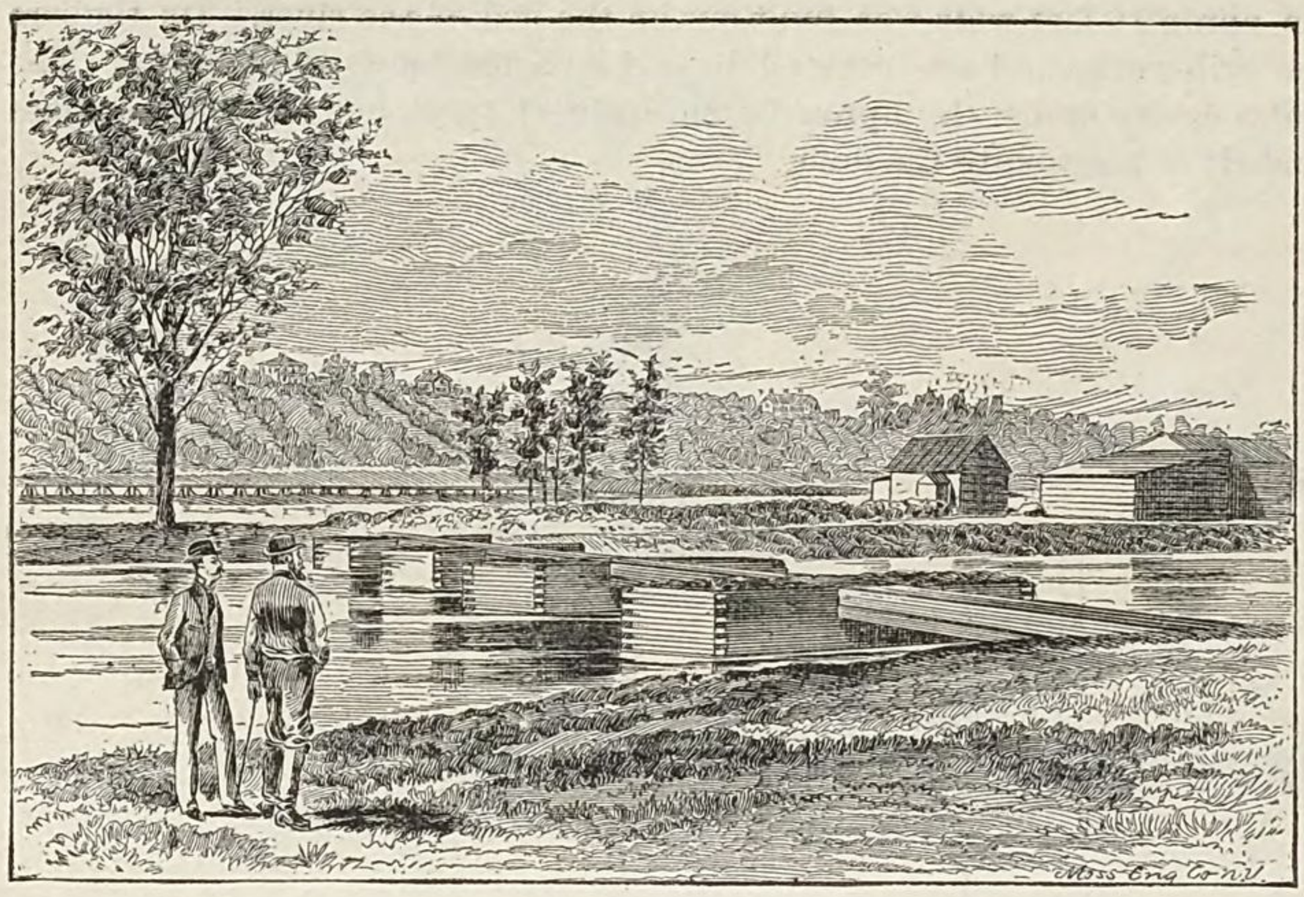
METHOD OF BUILDING.—To avoid expensive coffer-dams Captain Edwards used an ingenious method, which deserves description. He estimated that $2,000 were thereby saved in the cost of construction.

Starting from the old wing-dam, at the north bank, a light coffer-dam was built out, as shown in Figure 1, about 150 feet into the stream, turning the flow against the south bank. In the space thus left dry he built the parts marked A in Figure 2. Then, at distances of a few feet apart, the sets marked B B B were set up, leaving a space at the toe sufficient to shove in a plank between A and B. These sets are shown in plan in Figure 1. Then the sill-pieces, marked A in Figure 2, were boarded over. The first coffer-dam was then removed and replaced as the second coffer-dam, starting from the other side of the channel at Grand Chute island. Back of this the dam was built complete. Coffer-dam No. 3 was then built. The whole flow of the river was now passing through the space A B in Figure 1, between the timber sets marked B B B in Figure 2. Behind the third coffer-dam the dam was completed out to B, Figure 1, with a waste-weir. The third coffer-dam was then removed. String-pieces, C C C, Figure 2, were pushed down against the sets B and held in place by the force of the current. Then over these planks were shoved down. This made a dam, and caused the water to flow over the waste-weir constructed back of the third coffer-dam. A clear, dry place was now left in the section A B, Figure 1, and the dam was then completed without removing the sets B B B. When all was completed these were cleared away.

The waste-weir is 3 feet lower than the crest. At the north end a length of 75 feet is left permanently open, but for the rest of the length there is a system of needles, whose object has been already described in treating of the water-power. These needles are 5 by 3 inch scantling, which are let down close together over the waste-weir, and so close it when required. A platform, shown in Figure 3, extends along the dam, on which the operator stands. He shoves a needle down into the water, and the force of the current carries the lower end snug against a cleat on the floor of the weir, while the platform supports the upper end. These needles and the platform are shown in the view of the dam.

MISCELLANEOUS CONSTRUCTIONS.

CHEAP FORM OF COFFER-DAM.—A very cheap and yet effective form of coffer-dam is much used on the Lower Fox, where the stream is so steady and shallow as not to require expensive structures. This consists of sets formed of logs 6 or 10 feet long, with two legs at one end, string-pieces, and boards. The sets are first put in position, and the lower end is held down by stones; string-pieces are then spiked across these, and on them thin boards are nailed.



BULKHEADS OF THE HYDE & HARRIMAN CANAL, LOWER LEVEL, APPLETON, WISCONSIN.

WOODEN BULKHEADS.—The bulkhead at the upper part of the Hyde & Harriman canal, at the lower level at Appleton, is illustrated here. The object is to shut off the water from the canal in case repairs are necessary. Three timber cribs, filled with stone, are placed in a row across the channel at equal distances apart, and connecting them is a frame and plank roadway. Directly below, on the bed of the canal, is a timber sill-piece, extending from crib to crib. When necessary, planks can be shoved down into the water, with their lower ends resting against the sill-piece, and the water can thus be effectually shut off from the canal. The roadway can be employed as a bridge. This form of bulkhead is much used.

TRIBUTARIES OF THE LOWER FOX RIVER.

The only tributaries of any importance in a consideration of the water-power are the two streams which unite to flow into lake Winnebago at Oshkosh, on its western shore. These are the Upper Fox, from the southward, and the Wolf, from the north. They are the feeders of the great reservoir which make the Lower Fox so valuable, and on this account are of importance. The tributary branches extend so as to drain almost the whole lake Winnebago basin. All the other streams emptying into lake Winnebago are of small size.

WOLF RIVER.

This river rises about 30 miles south of the line between Wisconsin and Michigan, and flows in a general southerly direction 145 miles, measured along its general course, to the Upper Fox, which it enters about 10 miles from lake Winnebago. It is called a tributary of the Upper Fox, but, as in the case of the Missouri and the Mississippi, the tributary is the master stream. For this reason it is thought best to discuss it alone, and not as a branch of the Upper Fox.

On the map it will be noticed that the tributaries are almost entirely from the west—a fact due to its wedge-shaped valley, with a long gradual western slope, and a sharper slope on the eastern side. The cause of this peculiar formation of valley has already been given, and the statement has been made that at one time the Wolf river ran to the Mississippi through the lower portion of the Wisconsin River valley.

SURROUNDING COUNTRY.—The country about the Wolf has lain undisturbed until late years. It is true that the pine woods which covered the country have been largely cut away along the lower part of the rivers, but above Shawano, which is 40 miles from the foot of lake Winnebago in a straight line and 70 miles from the mouth of the river (map measurement), the pine woods still remain, although the lumbermen are hard at work there. It is said that there are over two billion feet left upon the upper Wolf and its tributaries. The country, then, except at the lower portion of the river, is still a wilderness. The business of the region has been lumbering, but the products of the farm are beginning to take a prominent place. The principal town is Shawano, the county-seat of Shawano county. Its population is about 1,000.

THE RIVER BELOW SHAWANO.—Shawano seems to mark the dividing point between two portions of the river, differing to some extent in their characteristics. Here the river leaves the metamorphic base rock, already described as forming the foundation for the other rock layers, and runs along the stratified rock. In this vicinity also it crosses the old coast-line of lake Michigan and enters the region of red clay, the lacustrine deposit. Below

Shawano the stream is sluggish, falling only about 50 feet to lake Winnebago in a distance of at least 70 miles. The banks are low, and in high water the surrounding flats are all covered. In heavy freshets the river becomes several miles wide. This characteristic has been already mentioned as of some importance in aiding lake Winnebago in its action as a reservoir. In freshets the river takes some time in finding its way among the swamps and adjoining lowlands, and after these are filled an equally long time is consumed by the water in running out; so that a freshet which in many streams would be spent in a few days is thus distributed through a much longer period.

Shawano is considered the head of practical navigation, and the United States engineers have been engaged in making surveys of the river up to that point for the purpose of improvement. Colonel D. C. Houston, major of engineers, stated in his report that the present or the prospective business of the region does not warrant any large outlay. The plan of improvement appears to be the removal of snags and leaning trees and the excavation of sand-bars. Near Shawano the width averages 80 feet, with a mean low-water depth of about 2.8 feet, and the course is very winding. It will be evident, from what has been given, that there is no available water-power on the river below Shawano.

THE RIVER ABOVE SHAWANO.—Above Shawano the stream is more rapid. Lac Vieux desert, the head of the Wisconsin river, is about 30 miles north-northwest of the source of the Wolf, and is 951 feet above lake Michigan. From the east and west directions of the intervening streams it does not seem probable that the upper waters of the Wolf are many feet below those of the Wisconsin. But suppose there is a descent of 200 feet in the space between them; this would make the head of the Wolf river 751 feet above lake Michigan. Shawano is about 221 feet above the datum plain; hence the river falls, according to this estimate, 530 feet from its source to Shawano. The distance is about 75 miles, and the average fall per mile is a little over 7 feet. It is thought that this estimate is slightly below the true figures.

The upper section of this river appears more promising for power, and it is in this portion that the water-power is located. The country there is as yet so undeveloped that these powers are of small value, but when it becomes more settled and the land is cleared for farms the conditions will be changed. For many years, however, the upper Wolf will probably be left unimproved. The lumber companies have upon the main stream and its upper tributaries at least twenty flood-dams, which are used for ponding the water, and then, when the stream is full of logs, the gates are opened and these logs flushed down on the high water thus produced.

FLOW OF THE RIVER.—The low-water discharge at the mouth of the Wolf river, as estimated on August 9, 1878, was 1,608 cubic feet per second. The low-water volume below the outlet of Shawano lake, at Shawano, was estimated on August 30, 1879, to be 633.7 cubic feet per second. The discharge at Shawano would give, with 10 feet head, a low-water power of 719 theoretical horse-power, or, with an efficiency in application of 75 per cent., 539 available horse-power.

MILLS ON THE WOLF RIVER.—The only utilized power on the entire river is at Keshena, about 7 miles above Shawano. At this place is an Indian reservation, and the government has a grist- and saw-mill, run by water-power, to supply the wants of the Indians.

TRIBUTARIES OF THE WOLF RIVER.

The principal tributaries of this river are on the west side, and of these the farthest north is Red river. Flowing about 40 miles (map measurement) southeast, it enters the main stream 3 miles above Shawano. Then the Embarrass river, the longest tributary of the Wolf, enters at New London, after flowing about 60 miles in a general southeast direction. The Little Wolf, the third large tributary, enters from the west about 4 miles below the mouth of the Embarrass river, and is about 45 miles long. The tributaries on the east are a small stream, the Shiocton, about 20 miles long, which enters some 10 miles above New London, and the outlet of Shawano lake, entering at Shawano. This lake is 5 miles long, and averages about 2 miles wide, and the outlet is not over 3 miles from the Wolf river. The tributaries on the west have considerable fall, and the northern ones especially are described in the geological reports as being frequently broken by rocky rapids. They run through the same character of country as does the upper Wolf itself. Upon these tributaries are many water-powers of moderate size, and several of them are in use upon the more southern of the streams. On the Embarrass the lowest mill is at the village of Embarrass, and there are one or two above that place. The fall on this river is mostly situated above the town of that name, which is 20 miles from its mouth. Below, the descent is slight. The water-power of the Little Wolf is not so great as that of the Embarrass, but it is more improved, and there are beside a mill at Manawa, two above that place, and two below it; also a mill on the outlet of Shawano lake.

These mills on the Wolf river and tributaries are grist- and saw-mills of a small capacity, as might be expected in a newly-developed portion of the country, and average about 50 horse-power under an average head of 8 to 10 feet

UPPER FOX RIVER.

It has been seen that the Upper Fox forms a part of the navigation route from the great lakes to the Mississippi, and its course lies most conveniently for such a purpose. The river rises in Columbia county and flows west-southwest about 20 miles to within 1½ miles of the Wisconsin at Portage. There, as already described under the title of "Physical conditions of the basin", it is separated from the Wisconsin only by a low, sandy plain. At this point it turns at right angles and flows north for about 16 miles, and then northeast to lake Winnebago.

ANCIENT COURSE OF THE UPPER FOX.—It is the opinion of those best capable to judge that at one time the current of the Upper Fox was reversed; that the Wolf river occupied this valley to Portage, where it entered the present Wisconsin valley, and that the original of the Upper Fox river was that portion above Portage, merely a small tributary of the ancient Wolf river. The peculiar bend in the river at Portage is entirely in accord with this view, which has been previously discussed.

Unlike the Lower Fox, the river flows with a gentle current, and the aim of the United States engineers in the improvement has not been so much to overcome the fall of the stream as to obtain a channel of sufficient dimensions for the passage of boats. From lake Winnebago to Portage, where the route changes to the Wisconsin river, the navigation is by slack water, produced by several dams with locks. The following table shows the distances and elevation along the Upper Fox from the mouth to near Portage:

Place.	Intermediate distance.	Fall of water between places.	Total distance.	Elevation above lake Winnebago.
	Miles.	*Feet.*	*Miles.*	*Feet.*
Oshkosh	0.00	0.00	0.00	0.00
Eureka	22.50	5.20	22.50	5.20
Fiddler's Bend	16.50	5.98	39.00	11.18
Princeton	12.25	4.92	51.25	16.10
Mechan river	5.75	2.57	57.00	18.67
Head of lake Puckaway	6.25	0.95	63.25	19.62
Montello	15.25	4.93	78.50	24.55
Governor's Bend lock	21.00	5.95	99.50	30.50
Fort Winnebago	5.50	2.60	105.00	33.10

The Wisconsin river at Portage is 9.51 feet above the Upper Fox at fort Winnebago, 2⅓ miles distant by canal, and the river falls only 33 feet in a distance of 105 miles between fort Winnebago and lake Winnebago. The average fall per mile is 0.31 feet, and there are no special concentrations of the descent. The river expands in Buffalo lake to half a mile wide, a quiet sheet of water, largely filled with reeds and wild rice, and at the foot of this lake is the village of Montello. Fifteen and one-quarter miles below Montello the stream enters lake Puckaway, which is 8¼ miles long and from 1 to 2 miles wide; but below lake Puckaway its course is more like a river, the banks being higher and the channel deeper. Ten miles from the mouth the Wolf river enters, and below the mouth of the Wolf the river passes through lake Butte des Morts, finally reaching lake Winnebago at Oshkosh.

CUT-OFFS.—There are many bends in this river, some of which have been cut off by the improvements for navigation, and others have been changed in a very accidental method. In one place the Indians were in the habit of dragging their canoes across the neck, until finally, in high water, a current passed along the channel which they wore, and the bend was cut off; in another place the building of a post fence across a neck of land has been the cause of a cut-off.

It may be readily imagined that there is little water-power upon the Upper Fox, and the conclusion is a correct one.

MILLS ON THE UPPER FOX.—There are two mills only, and one is at the dam and lock at Montello; this is a small grist-mill, with two run of stones, and when there is a good stage of water the head is 3 feet, but sometimes it is as low as 10 inches. The wheel is a large turbine, and as there is plenty of water for this one mill it can run under such a small head. The second mill is at Pardeeville, 8 miles above Portage, and has three run of stones. In June, 1881, the dam, which had been carried away by high water, was being rebuilt.

DISCHARGE FROM THE WISCONSIN RIVER.—There is an available power at Winnebago lock, 1½ miles below Portage, where the canal from the Wisconsin enters the Upper Fox. In low water the Wisconsin is 5 feet above the Upper Fox at Portage, and this is the available head at the lock; but in high water there is from 9 to 11 feet difference in the levels. The larger portion of the flow of the Upper Fox at Winnebago lock comes from the Wisconsin through this canal, and it is the surplus after navigation is supplied which could be utilized for power. This surplus is stated to be 208 cubic feet per second, and it is probable that the government would allow the use of this power, subject to proper restrictions. The theoretical power is 118 horse-power, sufficient to supply a fair-sized flouring-mill.

The Wisconsin river, overflowing into the Upper Fox in high water, produces an element of unsteadiness in the flow of the latter stream rather difficult to estimate. The main overflow is through the channel of Big slough or Neenah creek. The low-water volume of the Upper Fox just above the junction with the Wolf was estimated on August 9, 1878, to be 1,043 cubic feet per second.

TRIBUTARIES OF THE UPPER FOX RIVER.

The principal branches of this river are on the northern side. Three in number, they start as clear, steady springs, running from the sand-ridges of the drift covering that portion of the basin. They are each about 20 miles long, and would be considered unimportant streams except for the fact that their fall, combined with their steadiness of flow, makes them of real value for small water-powers. Their sources are 200 to 300 feet above their mouths. The Montello river, entering the Upper Fox at the foot of lake Buffalo, where Montello is situated; the Mechan river, about six miles below lake Puckaway, and the White river, emptying into the main stream about 12 miles below the Mechan river, are the streams referred to. The Montello river at the mouth formerly ran around a spur of syenite, which there projects above the soil. A dam was thrown across the channel, and the water deflected so as to run down over the rock, and a flour-mill and woolen-mill now use the power. The head is 11 feet. The flouring-mill uses about 75 horse-power, and the woolen-mill about 50. They do not use over one-half the power of the stream at that head; hence the total horse-power on this estimate, at 10 feet head, is not less than 225. The flow of this stream is very uniform, and as the head can easily be increased to 16 feet there is every facility for utilizing its full power. The rise above the dam does not exceed 3 feet in high water.

Above this power are three more mills of about three run each. It is probable that there is more available water-power upon the Montello river than on the whole Upper Fox. The Mechan and White rivers are similar in their characteristics to the Montello, which has been given as an example. At Princeton a small stream enters the Upper Fox, and under a head of 30 feet it supplied a mill of two or three run, using about 20 horse-power.

The region of the Upper Fox is under a much better state of cultivation than the valley of the Wolf, as it has been settled much longer.

The syenite referred to at Montello is a very compact red variety. Quarries have been lately opened there, and the prospects are that the stone will be of value. It has been used to some extent in Chicago for paving blocks, into which it readily splits.

RIVERS OF THE REGION NORTH OF THE LOWER FOX RIVER SYSTEM.

The rivers of importance emptying into lake Michigan north of the lake Winnebago basin are the Oconto, Peshtigo, Menominee, and several streams in the upper peninsula of Michigan. The instructions in pursuing the field-work were to omit the area lying in Michigan, and, as the time at disposal was limited, a personal visit was made to the Menominee river only. The Oconto and Peshtigo rivers have drainage areas of 1,017 and 1,123 square miles, respectively, and as their headwaters are elevated several hundred feet above lake Michigan, there is considerable fall in their beds. On the upper waters especially are many rapids. At the falls of the Oconto, by including the rapids, 60 feet fall is available, and on both streams are many available powers. By comparison with the Menominee, the power of each at the mouth, under 10 feet head, is estimated to be about 560 theoretical horse-power in ordinary low water. The country lying west of Green bay, along the Oconto, Peshtigo, and Menominee rivers, is still a wilderness, with the exception of the advances of civilization along the shore line of Green bay, the villages started by the iron interest of the Menominee range, and a small amount of land cleared for farming.

The great industry of this region in the past has been lumbering, and a pine forest covered the surface about as far south as the southern extremity of Green bay. Owing to extensive fires which occurred in recent years, this is largely burned off along the Oconto and Peshtigo rivers, but on the Menominee and its branches the woods still exist in their primitive state over large areas. It is along the Menominee that the most active lumbering is now done, and logging-camps are located each winter far up toward the headwaters. The famous Menominee iron mines are likely to lead among the industries of the section, but lumbering has been the main source of wealth in the past, and will be a prominent business for many years to come.

DESCRIPTION OF THE LUMBER BUSINESS.—The system of operations employed on the Menominee is the same general plan pursued throughout the lumber regions of the Northwest.

Lumber companies obtain from the state lands containing valuable pine timber, as near as possible to the streams, and when the lumber is cut off the land is of little value to them, and rather than pay the taxes they allow it to revert to the state. In the early winter men are engaged (in the Northwest largely Scandinavians and Germans, who form a great part of the population), and these are sent off into the woods belonging to the company, where log huts are built, and the men settle down to a winter's work. Supplies are taken to them, usually from the companies' own supply stores, and, contrary to what might be supposed, the men live unusually well, canned vegetables, meats, and fruits, along with many other necessaries and luxuries, being furnished to them; and if the food is not the best, or the cook is not liked, the company is sure to hear of "grumbling in the camp". Some of the men are choppers, and others are engaged in hauling the logs with either horses or oxen. A depth of from 18 inches to 2 feet of snow is considered best for hauling; but sometimes there is too little or too much, and then the work is very much impeded. The logs are usually cut in lengths of from 14 to 16 feet, and are hauled to the banks of the nearest stream of sufficient size to carry them. It is on this account that the timber away from the streams is left until the last. Each company has its distinctive mark upon its logs. When the winter breaks up and the streams are swollen by the melted ice and snow, and, later, by the spring rains, the work of the drivers begins. They start the logs on their journey down the rivers and follow along with them, breaking up jams where the logs are piled up in masses by some obstruction, and sort the logs, guiding those of each company into the pocket belonging to it when the destination is reached. On the Menominee there is what is called the Menominee River Manufacturing Company, incorporated in 1866, which is simply an organization for effecting this driving and delivery in a systematic manner. This company builds dams for holding the logs, blasts out the rapids, etc., to make driving better, and drive the logs, charging from fifty to sixty cents per thousand board feet for driving, sorting, and delivering the logs in the pockets of the several steam saw-mills at the mouth of the river. The owners of the timber lands upon the upper portion of the river pay something toward the improvement of the stream, as it makes their property more valuable.

The logs are sawed into boards, and the waste is worked into lath and shingles in the mills at the mouth of the river. The lumber is largely rafted across Green bay into Sturgeon bay, on the peninsula opposite, where there is a ship-canal about 5 miles long, connecting with lake Michigan. Boats are there loaded with it, and carry it to different ports, Chicago receiving a large portion.

In 1875 there were 602,285 logs passed down the Menominee river, yielding 112,056,280 board feet, and in 1872 142,917,228 board feet passed down the river. During the season of 1880 240,660,524 feet of pine passed through the booms of the Menominee River Manufacturing Company.

IRON MINING.—The ore beds of the Menominee region are explored from a little below the Sturgeon river, in Michigan, west, all along the Menominee and its tributaries, and to some extent in Wisconsin also. For over thirty years it has been known that there was iron there. In the winter of 1873–'74 the first shipment of ore was made; but in 1877 the Chicago and Northwestern railroad built a branch up to Quinnesec, on the Menominee, and since that time the advance has been rapid. The rock of the region belongs to the metamorphic base, already described as forming the foundation for the rock layers of the eastern part of Wisconsin, and consists chiefly of granite and schists of various kinds. The ores are hematites, specular ores, and magnetites principally, and, as they contain scarcely any sulphur and a small amount of phosphorus in the average specimen, they are especially valuable for the manufacture of Bessemer steel. This region is becoming very prominent, and many new mines are proposed.

When the lumber and the mining interests of this region are described there remains little else to consider, for the country is almost entirely undeveloped except in these respects. It is true, however, that in sections along the Oconto and Peshtigo active farming is beginning.

FIELD FOR MANUFACTURING.—It may readily be imagined that the amount of utilized water-power is small, and this is the case, but not because of any absence of the power unimproved. The industries using power have not yet started to any extent, with the exception of saw-mills. These are located at the line of navigable waters, and principally use steam-power. There are great quantities of the crude material for the manufacture of wood-pulp, and already there has been talk of erecting mills on the Menominee, using water-power for this purpose. This and the making of paper are forms of industry well adapted to lead among the manufactures of a new district, and they will very likely lead upon the Menominee. As the country is settled flouring-mills and other kinds of manufactories may be built; but at present the only two mills upon the Menominee are near the mouth, a paper-mill and a flouring-mill, to be afterward described. At the mouth of the Menominee are two towns: Menominee, in Michigan, with a population of 3,288, and Marinette, in Wisconsin, with 5,412 inhabitants. Peshtigo, on the Peshtigo river, has 3,517 inhabitants, and Oconto, on the Oconto river, 4,171 inhabitants. These towns are on the line of the Chicago and Northwestern railroad, and are the centers of trade for their respective regions. Oconto and the two towns on the Menominee have lake ports, more or less satisfactory, and improvements are being made in their harbors.

MENOMINEE RIVER.

This stream through its entire length is the boundary between Michigan on the north and Wisconsin on the south. Formed by the junction of the Bois Brulé, or Burnt Woods, river and the Michigamme, it flows southeast 104 miles by map measurement into Green bay at about the middle of its western shore.

DIMENSIONS OF THE DRAINAGE BASIN.—The drainage basin of 4,113 square miles is very irregular in outline. Narrow at the mouth, it widens out to an average of about 40 miles across, and sends an arm away north, so that the extreme sources are within 10 miles of the waters of lake Superior in Keweenaw bay. Thus, it nearly extends clear across the center of the upper peninsula of Michigan. At the nominal head of the river it already has a drainage area of 1,769 square miles, for the Bois Brulé and Michigamme are each large streams. Farther down it receives the Pine and Pike rivers from Wisconsin, and the Sturgeon and Little Cedar from Michigan, beside numerous smaller streams (see the table of drainage areas of the Menominee and its tributaries, given further on). The Bois Brulé continues westward, the boundary line between the two states.

The region drained by the Menominee river is yet a wilderness, except where the mining villages have sprung up within late years. The lumbermen have not yet made serious inroads upon the upper waters, and the stillness of the stately pine forests holds its sway. The deer, which are disappearing so rapidly in other sections, there find a safe retreat, and the sportsman can yet see trout as plentiful.

Although no industries yet cluster about the numerous falls on the Menominee, it is only a question of time before the resources of the country will be developed. A personal visit was made to the mining village of Quinnesec. At Marinette Mr. Burleigh Perkins, a gentleman who has explored every mile of the region under the employ of the Menominee River Manufacturing Company, kindly gave much information for this report.

GEOLOGICAL CHARACTER OF THE MENOMINEE BASIN.

The main geological features described among the first pages devoted to the Lower Fox river also rule here The Archæan base, with the succeeding outcropping layers of unmetamorphic rock, which characterize eastern Wisconsin extend almost unchanged along the areas of the Oconto and Peshtigo rivers, the Menominee river, and through the upper peninsula of Michigan. Farther south these layers have an inclination to the east and southeast, and the lines of outcrop of the harder rocks, such as the lower magnesian and Trenton limestones, form a succession of steps, as shown in the east and west section through lake Winnebago, although not so prominent as is the case there. The surface is very largely covered with the drift left by the ice-cap of the glacial period, and the Menominee and all its tributaries, down to about the mouth of the Pike river, flow over the metamorphic base rock, consisting of granite, gneisses, schists, etc. It is in this region that the iron mines are located. Below the mouth of Pike river it flows across the Potsdam sandstone for about 10 miles, then it flows on the next higher layer, the lower magnesian limestone, for about 18 miles, and finally leaving that, it crosses the Trenton group of limestones for about 8 miles to its mouth.

INFLUENCE OF THE ROCK STRATA.—Attention has already been given to the very marked influence of the geological structure upon the Wolf river of the lake Winnebago basin, and as the same structure holds farther north it has had an effect similar in a general way upon the streams there, the Oconto, the Peshtigo, and the Menominee. Because of the general slope to the southeast the tendency of the streams is to flow in that direction, but the terraces of rock along the line of outcrop have forced them to flow northeast or southwest along these outcrops until they could find a passage. To this cause are due the bending and the wide sweeps of the rivers under discussion. It will be noticed that in their upper portions the Wolf, Oconto, Peshtigo, and Menominee have more or less parallel courses southeast. There they flow upon the Archæan base. So soon, however, as they strike the region of stratified and unmetamorphic rock their courses vary.

The Wolf, as it existed previous to the glacial period, traversed the Potsdam belt, and, striking the terrace of lower magnesian, had to run across the state of Wisconsin before it could find a passage through this obstruction by the present Wisconsin River valley. The cause of its change to the modern course has been already mentioned. The Oconto, Peshtigo, and Menominee were more fortunate, and succeeded in keeping their general southeast course across the successive belts of rock; but they, too, found some difficulty, and have to run long stretches along a line of rock before a point is reached where they boldly break across the belt of outcrop.

The Menominee river flows in a general southeast direction to about the mouth of Sturgeon river; from there it gradually bends to the south, and appears to follow the line of outcrop of the Potsdams sandstone down to the mouth of the Lowland river. This is apparently due to the Potsdams opposing a barrier in its course, but we cannot assert it positively, as the courses of the Wolf, Oconto, and Peshtigo are unaffected by the sand rock, passing unchanged across it. These barriers are usually where a hard rock is underlaid by a soft variety. At the mouth of the Lowland river the course changes through more than 90 degrees, and passing directly across the belt of Potsdam sandstone the river encounters the projecting ridge of the hard lower magnesian limestone. Along this it flows northeast for 4 miles, when it suddenly succeeds in forcing a passage, and, breaking across at right angles,

runs southeast 4 miles further, when it strikes the terrace of Trenton limestone at the mouth of the Little Cedar river. This barrier of Trenton limestone causes the river to bend again and flow southwest for about 12 miles, when the stream finds a passage across the limestone, and flows about 8 miles southeast to Green bay.

It must not be supposed that these different layers of rock stand out in bold cliffs along the stream; on the contrary, the river flows in many places entirely in the drift accumulation. The rock formation has nevertheless had the influence just described.

The Peshtigo river, in endeavoring to cross the Trenton limestone barrier, runs northeast and comes within 3 miles of the Menominee at its lower bend. The idea is advanced by Professor Chamberlain, merely as a conjecture, that these two rivers formerly united at this point and crossed the limestone barrier in company by an old channel now filled with drift. There is evidence that they have not always had their present places of passage, and at this region is the lowest apparent point of the barrier in their basins.

MAIN TOPOGRAPHICAL FEATURES.

The country through which the Menominee flows is not mountainous, but many ridges give diversity to the surface. These are ranges or continuous ridges, a few hundred feet high perhaps. The bulk of the timber which covers the land is pine, but in places the light sand soil congenial to a pine growth is replaced by clay, and there the growth is hard wood. The transitions from one kind of timber to another are in many places very distinct, and sometimes a ridge covered with hard-wood timber will run far into a body of pine woods. About Chicagon lake there is a large body of hard timber, and when the land is cleared there will undoubtedly be localities where fertile farms can be wrought out of the wild surface left by nature.

VOLUME OF THE MENOMINEE RIVER AND ITS POWER.

ESTIMATE OF FLOW FROM THE RAINFALL.—No estimates of the flow of the river were obtainable, and no attention has been given to calculating this factor from the annual precipitation and from comparison with adjoining streams on which gaugings have been made. The results, which only claim to be mere approximations, are given in the accompanying table.

The upper Wisconsin and the Wolf flow through somewhat similar sections of country, except that the upper Wisconsin has more swamps and lakes than the latter. The area drained by the Wisconsin above Portage is stated by the United States engineers to be 8,200 square miles, and the extreme low-water discharge at that point 2,800 cubic feet per second, or about 0.34 cubic feet per second per square mile of drainage area. The discharge of the Wolf river at the outlet of Shawano lake has been gauged in about ordinary low water at 633.7 cubic feet per second. The area tributary is 887 square miles. This would make the ordinary low-water flow per second per square mile of drainage basin on the upper waters 0.71 cubic foot per second, which is probably excessive.

For the entire basin of the Wolf river the ordinary low-water discharge per square mile of drainage area is 0.43 cubic foot per second, and for the entire lake Winnebago basin, with a rainfall averaging 30 to 32 inches, it is 0.413 cubic foot per second. The average precipitation upon the Menominee basin is, as near as can be estimated from the meager records in that region, 35 inches, while along the neighboring rivers south it averages about 32 inches.

In view of all these facts, it has been concluded to assume the ordinary low-water discharge of the Menominee basin as 0.46 cubic feet per second per square mile of drainage area; that is, the ordinary low-water flow is at the rate of 17.8 per cent. of the average precipitation. This gives a power, under 10 feet head, of 2,140 theoretical horse-power at the mouth and 921 theoretical horse-power at the head of the river.

TABLE OF DISTANCES, DRAINAGE AREAS, LOW-WATER VOLUME, AND POWER AT DIFFERENT PLACES ON THE MENOMINEE RIVER.

Place.	Distance from preceding station.	Drainage area tributary to it.	Amount of yearly precipitation.	Estimated total volume of precipitation per second.	Ratio of low-water discharge of stream to total volume of precipitation.	Estimated ordinary low-water discharge of stream per second.	Theoretical horse-power under 10 feet head.
	Miles.	*Sq. miles.*	*Inches.*	*Cubic feet.*	*Per cent.*	*Cubic feet.*	
Head of river	0	1,769	35	4,561	17.8	812	921
Mouth of Pine river	14	2,419	35	6,237	17.8	1,110	1,259
Mouth of Sturgeon river	18	2,934	35	7,565	17.8	1,347	1,528
Mouth of Pembinebemon river	10	3,156	35	8,137	17.8	1,448	1,643
Mouth of Pike river	18	3,566	35	9,194	17.8	1,637	1,856
Mouth of Little Cedar river	22	3,941	35	10,161	17.8	1,809	2,052
Mouth of river	22	4,113	35	10,595	17.8	1,886	2,140

In high water the power is immensely increased. The river is not especially uniform in its flow, although running in a timbered country; but it cannot be considered an unsteady stream, its character being medium in this respect. The superintendent of the paper-mill at the mouth said that after a heavy rain the river would rise to a maximum in about four days, stay at that stage about the same length of time, and then fall to the usual level in about four days more.

There are only three or four lakes of any size in the basin, and these mostly have limited drainage areas. The most important one is lake Michigamme, far up on the river of that name. This lake is shaped like a letter A, with arms about 6 miles long by half a mile broad. It is altogether probable that suitable sites for reservoirs could be found in the basin, and when the river is improved for power this matter may receive attention. Some of the tributaries are so uniformly rapid, as the Bois Brulé, that a high dam would only flood a very limited area. The clearing away of the timber and brush will undoubtedly have an injurious effect upon the stability of the river in the future, as has been the case in so many instances elsewhere.

FALL OF THE RIVER.—The extreme sources on the west are within 2 miles of Lac Vieux desert, the source of the Wisconsin, which is 951 feet above lake Michigan, and on the north they are at least 990 feet above lake Michigan, as lake Michigamme is 952 feet above the level of lake Superior. Thus the river may be considered to fall about 975 feet from its sources to its mouth in a distance by water of about 160 miles. This descent is scattered in local concentrations all along its course, and rapids characterize the river from the source to the mouth

Through the kindness of Mr. E. H. Johnson, chief engineer of the Chicago and Northwestern railroad, the approximate elevation of the river at the railroad crossing, 3 miles above the mouth of Pine river, is ascertained to be 475 feet above lake Michigan, and of the Sturgeon river, at the crossing, 2½ miles above its mouth, 253 feet above the lake. Hence, in the 56 miles (map measurement) from the extreme western sources in the Mequacumecum to the railroad crossing above Pine river the Menominee falls approximately 475 feet, an average of 8½ feet per mile, and from the railroad crossing to the mouth of Sturgeon river, a distance of 18 miles, it falls approximately 225 feet, an average of 12½ feet per mile. In this distance occur the two Quinnesec falls. In the 72 miles from the mouth of Sturgeon river to the lake it falls approximately 250 feet, an average of 3½ feet per mile.

To the consideration of the chief rapids on the main river we will now turn our attention.

THE RAPIDS OF THE MENOMINEE RIVER.

The information contained under this head was almost entirely obtained from Mr. Burleigh Perkins, of Marinette, to whom allusion has already been made.

It will be evident, on reading the following account, that there is an immense amount of water-power on the Menominee awaiting development, the concentration of the descent in numerous rapids and falls supplying remarkably fine opportunities for improvement. All that is wanting is the greater development of the whole region, and this is bound to occur in due time. Any works for the utilization of the power would have to be so constructed as not to interfere with the manufacturing company in the driving of logs; but dams, etc., could be built so as to be no hinderance to the passage of logs.

It must be remembered that only the heavy rapids are described, and that undoubtedly many water-powers, available so far as the river is concerned, exist in the intermediate distances.

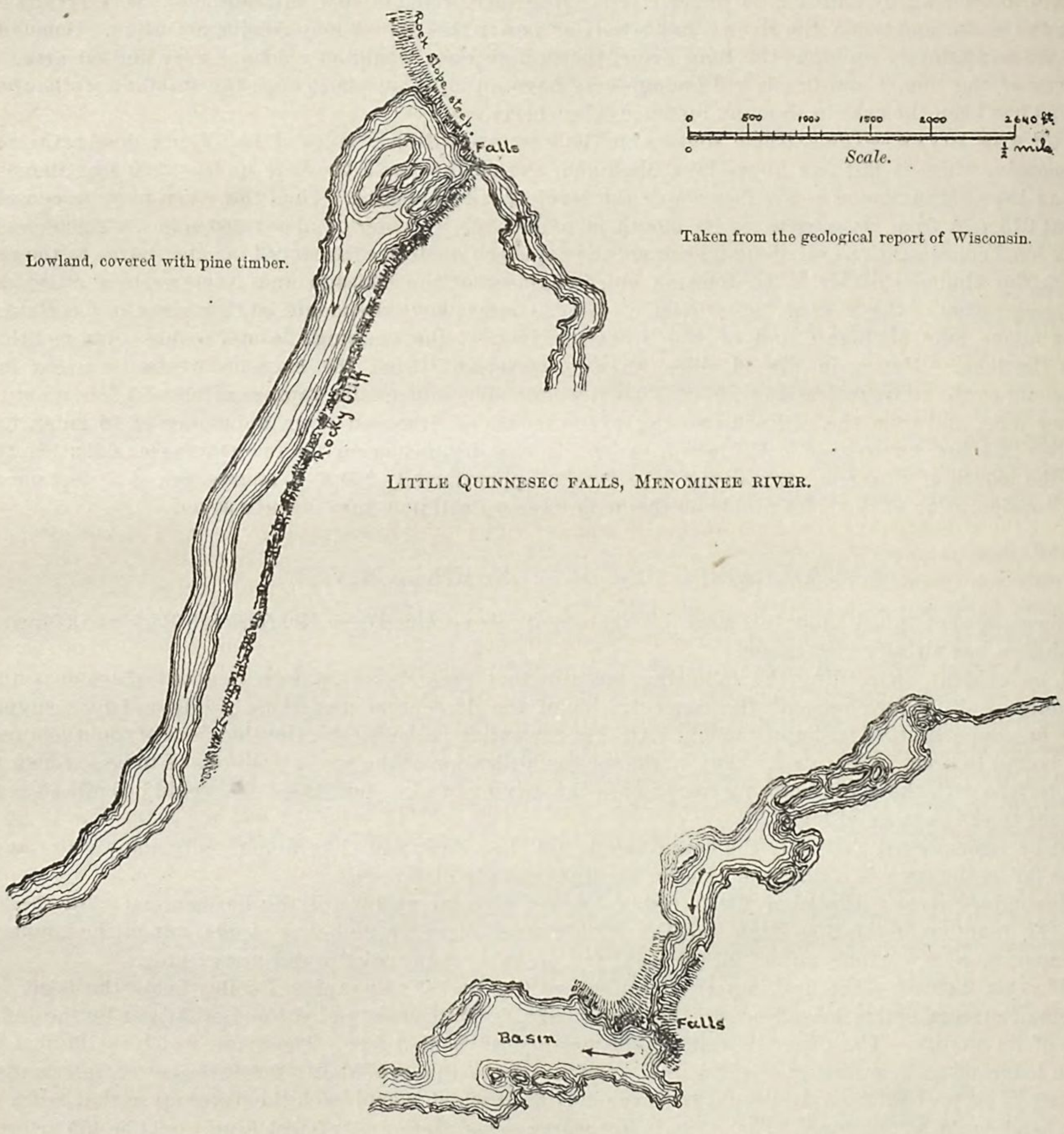
The Menominee river varies from 200 to 600 or 700 feet wide far up toward the headwaters. For the first 7 miles from the junction of the Bois Brulé and the Michigamme there are no heavy rapids, but in the language of the lumbermen, there is "strong water" all the way, and probably many good water-power sites.

BAD WATER RAPIDS.—The first important rapids are the Bad Water rapids, 7 miles below the head of the river. A small stream enters here from Spread Eagle lake, in Wisconsin, called the Bad Water by the Indians, on account of its quality. The direct descent at the locality is about 5 feet. The river, which is 180 feet wide, runs over a ledge of rock, probably a schist or a granite. As to the availability for water-power, information is wanting; but in all probability a dam could be reasonably built which would back the water up so that much more than 5 feet head could be obtained. The ordinary low-water power there under 5 feet head would be 455 theoretical horse-power. The Menominee River branch of the Chicago and Northwestern railroad passes about 3 miles south on its way to the young mining town of Florence, in Wisconsin.

TWIN FALLS.—Just below Bad Water rapids 3 or 4 miles are the Twin falls. These consist of two vertical falls of 12 feet each, about half a mile apart. With 12 feet head the ordinary low-water power would be 1,130 theoretical horse-power, making a total for the two falls of 2,260 horse-power. Both falls are said to be well adapted to improvement for water-power, and they are near where the railroad crosses the river into Wisconsin.

PINE RIVER RAPIDS.—Next in course are the Pine River rapids, near the mouth of Pine river, which are half a mile long and have 6 feet fall. An island divides the river into two channels with rocky beds. Above the mouth of the Pine river the ordinary low-water power for 6 feet head is 566 theoretical horse-power; below the Pine river, 730 theoretical horse-power.

BIG QUINNESEC FALLS.—Seven miles below the Pine river, and 4 miles from Quinnesec, the most prominent of the villages in that section, are the Big Quinnesec falls, they and Little Quinnesec falls, 4 miles below, being the two heaviest falls on the river.



LITTLE QUINNESEC FALLS, MENOMINEE RIVER.

BIG QUINNESEC FALLS, MENOMINEE RIVER.

At Big Quinnesec falls the river narrows to hardly more than 50 feet wide (map measurement) between rocky banks of greenstone, a variety of igneous rock. Immediately at the foot of the falls the river widens out, and

about 800 feet down is 700 feet across. Above the falls it has been running east of north, and there it turns directly east. The banks are 80 to 100 feet high on the Wisconsin side and 30 to 40 feet high on the Michigan side, and the fall proper is a vertical pitch of 60 feet. There is 40 feet of rapid descent above the fall, and 20 feet in the first 900 feet below, the total fall being 120 feet. The total theoretical power with this 120 feet head in ordinary low water is 14,905 horse-power. It seems probable, from the description given of the locality, that it would be very costly to improve the full fall of 120 feet.

LITTLE QUINNESEC FALLS.—Four miles below are the Little Quinnesec falls. For the greater portion of this distance there is quiet water, and the shore deposits are considered by Major T. B. Brooks, who reported on the geology of the district, to indicate the presence of a lake there at a comparatively recent date. Above Little Quinnesec falls the river runs southwest, but at the foot it suddenly turns at right angles and runs southeast, the water surging down an incline of about 45 degrees, and then taking a plunge into the comparatively still water of the basin below. The total fall is about 80 feet. Above the fall a short distance the river is 250 feet wide but narrows down at the pitch to about 50 feet. Immediately below the fall the basin spreads out on the south to 900 feet wide, but 1,500 feet below the channel contracts to 400 feet in width, and in this basin are three or four parallel islands, the largest being 700 feet long by about 150 feet wide. The falls are hemmed in by heavy masses of greenstone and schist rock. Along the Michigan side a massive steep cliff of greenstone, at least 100 feet high, forms the bank of the river for a long distance, and on the Wisconsin side a somewhat similar rib of rock forms the bank of the basin for 600 or 700 feet from the fall, and then slopes away into ridges of more gradual inclination. The rest of the Wisconsin shore of this basin is low. There is a considerable area of level land covered with timber; then the hills rise gradually behind this, and the valley, probably of some small brook, trends away to the west. From the description given it will be seen that the banks adjoining the falls are steep and rocky.

There is not any apparent means of an extensive improvement of this water-power without great outlay of money, and even if only one or two industries were clustered close at the falls the expense would be great. Still, with the head of 80 feet, and an ordinary low-water power of 9,936 theoretical horse-power, the situation will be worth improving when the country becomes older and the value of water-power is increased. A deep snow and limited time prevented a very extensive exploration along the rocky cliffs, but from what was observed it seems probable that the only feasible way of improving this power on an extensive scale is to blast a race out of the rock, or else build flumes along the cliffs and supply manufactories from them. It is possible thus to carry the water along the Wisconsin bank and supply the power to mills upon the flats below. On the Michigan bank there is not much available space, but mills could be built out over the river, provided the high water is not there excessive.

On account of the great width of the river for a long distance down it does not seem probable that the rise is very heavy. A wagon-road could be constructed from the flats below the falls to Vulcan, a station on the railroad, about 6 miles east of Quinnesec. The latter town is about 3 miles north of the falls, and could not be so readily reached from below as Vulcan. The Menominee River Manufacturing Company would, of course, object to having the flow over the falls diminished to a great extent in logging times by side races. It has built cribs on each bank at the crest of the falls, to make the body of water deeper, and has done some work at the foot in blasting out a rock which splits many of the logs as they strike their ends upon it. The company has been considering the plan of damming the river some distance below and backing the water up over this rock.

SAND PORTAGE RAPIDS.—These rapids lie between Little Quinnesec falls and the mouth of Sturgeon river, and received this name because the Indians, in making their "carry" around a part of them, passed over a large amount of sand. The rapids are scattered along a distance of 6 miles, and in this space is 40 feet fall. The ordinary low-water power under this head would be 5,078 theoretical horse-power.

STURGEON FALLS.—The next sharp pitch below the Sand Portage rapids is Sturgeon falls, half a mile below the mouth of the Sturgeon river. This fall is in two pitches of 6 feet each. Above the falls the river is 200 feet wide, and below them it spreads out into a broad basin. The banks are rocky ledges, about 30 feet high. From the description which was given it may be conjectured that in order to utilize the power it would be necessary to blast out a race in the rock or to build a flume, and it was stated to be feasible to blast out a place in the bank below and build a mill right at the foot of the fall, carrying the water in a short flume. The ordinary low-water power with 12 feet head would be 1,831 theoretical horse-power.

NOSE PEAK RAPIDS.—In the next 15 miles are several small rapids, among them Nose Peak, about 1,000 feet long, with 4 feet fall. This would give, at an ordinary low stage, 605 theoretical horse-power, but undoubtedly a greater head than 4 feet could be obtained.

PEMENA FALLS.—One and a half miles below the mouth of the Pembinebemon river begin the Pemena falls and rapids. For a distance of 2 miles there are rapids, with a total descent of 60 feet, and then a vertical fall of 10 feet, where there are two islands, giving two principal channels. The rock is the metamorphic rock of the upper waters, in this case a slaty variety, probably a schist, with quartz veins. Pemena falls and rapids are considered good for the erection of dams. The location is about 12 miles west of the Chicago and Northwestern railroad. Under the total head of 70 feet the power at ordinary low water is 11,115 theoretical horse-power.

CHALK HILL RAPIDS.—About 8 miles below Pemena falls are Chalk Hill rapids. They are nearly 1,300 feet long, with 8 feet fall over a ledge of rock of slaty variety, and there is a good place for a dam. The ordinary low-stage power under 8 feet head would be 1,302 theoretical horse-power.

WHITE RAPIDS.—Four miles below, and about the same distance above the mouth of the Pike river, are the White rapids, with a fall of 20 feet in 3 miles. Two big islands lie in the center of the rapids. The bed is of gravel and bowlders (the drift), and the banks are good. There is a good location here for a dam, and the power could be well utilized. Under a head of 20 feet the ordinary low-stage power is 3,275 theoretical horse-power.

All the rapids down to this point are over the Archæan rocks. From the mouth of the Lowland river, while the stream is crossing the Potsdam sandstone, there are no heavy rapids; but while crossing the belt of lower magnesian limestone the course is southeast, and there are two rapids of note.

SIXTY-ISLAND RAPIDS.—Sixty-Island rapids, about 2 miles above the mouth of the Little Cedar, have only a slight descent, and the situation could not very well be made available for water-power.

GRAND RAPIDS.—One mile below occur the Grand rapids. These are 3 miles long, situated partly above and partly below the mouth of the Little Cedar, and have a fall of 25 feet. The bed is, of course, limestone. These rapids occur just where the river strikes the barrier of the Trenton limestone and turns southwest, and, like the Oconto falls, which are on the same geological horizon, they are caused by the river wearing down into softer strata of the rock, the hard cap not eroding so readily. There are good banks at the foot of these rapids for building a dam, and probably the power could be utilized. The ordinary low-water power under 25 feet head at this point is 4,954 theoretical horse-power, and the railroad passes one mile east of the rapids.

While following along the barrier of the Trenton limestone for about 12 miles to the last bend the river runs south-southwest, and the inclination of the bed is less, as might be expected, because the slope of the strata is toward the southeast.

TWIN ISLANDS RAPIDS.—These rapids are situated about 7 miles below the Grand rapids and 16 miles from the mouth of the river, with a length of three-fourths of a mile, and a descent in that distance of about 10 feet. The two islands lie one below the other, and divide the river into east and west channels. The bed is limestone, the banks steep, and there could be a dam built across each channel to the islands. The total length of this dam, it is said, would have to be about 700 feet. For a long way the old state road passes near the river, and by it access could be had to the towns at its mouth; but this road is not much used now. There was once a saw-mill, called Dr. Hall's mill, on the east channel, with 6 feet head, but this was removed when the lumbering interests began. The ordinary low-stage power under 10 feet head would be 1,995 theoretical horse-power.

At the lower bend the Menominee turns, and, running across the Trenton group of limestones in a southeast direction, finally reaches the lake level. As in passing the lower magnesian limestone, so here there are two sets of rapids.

SCHAPPEE'S RIFTS.—The first is Schappee's rifts, 5 miles above Marinette. These are half a mile in length, with a descent of 7 feet, and have an available head of 10 feet. There are good banks and a limestone bottom. The power at an ordinary low stage of the river would be 2,024 theoretical horse-power under this head.

RAPIDS AT MARINETTE.—The last series of rapids on the river are situated at Marinette, near the mouth. In their natural state there was probably about 10 feet fall, but the Menominee River Manufacturing Company has built three dams, one above the other, the upper one backing the water to the foot of Schappee's rifts. The total head from these dams is 19 feet. The head at the upper dam, about 1 mile above Marinette, is 7 feet, at the middle dam 5 feet, and at the lower dam 7 feet. At each of these there is available water-power. The theoretical power at an ordinary low stage would be as follows:

	Horse-power.
Upper dam	1,448
Middle dam	1,034
Lower dam	1,448
Total	3,930

This, with an efficiency of 75 per cent., would give 2,948 available or effective horse-power. The superintendent of the paper-mill stated that the ordinary low-water power available under 7 feet head was 1,000 horse-power. These calculations, based on the rainfall, make it 1,146 horse-power.

PRINCIPAL RAPIDS ON THE MENOMINEE FALL, AND ESTIMATED THEORETICAL POWER.

Name.	Fall, in feet.	Horse-power.	Name.	Fall, in feet.	Horse-power.
Bad Water rapids	5	455	Pemena falls and rapids	70	11,115
First Twin falls	12	1,130	Chalk Hill rapids	8	1,302
Second Twin falls	12	1,130	White rapids	20	3,275
Pine River rapids	6	566	Grand rapids	25	4,954
Big Quinnesec falls	120	14,905	Twin Islands rapids	10	1,995
Little Quinnesec falls	80	9,936	Schappee's rifts	7	2,024
Sand Portage rapids	40	5,078	Rapids at Marinette	19	3,930
Sturgeon falls	12	1,831	Total	450	64,231
Nose Peak rapids	4	605			

Of course, this table does not represent the total theoretical power of the river, as only a portion of the total fall is taken. It must not be forgotten that many of the amounts of fall given are only estimates made by an informant perfectly familiar with the stream; still, the figures given are moderate, and will serve to give some idea of the water-power lying idle.

UTILIZED POWER UPON THE MENOMINEE.

The only power used is from the lower dam at the mouth.

In 1831 permission was obtained from the Menominee Indians, upon the payment of certain supplies, to build a grist-mill on the river. This was built in 1832 on the Wisconsin bank, a short distance above the present crossing of the Chicago and Northwestern railroad. The next mill, a saw-mill, already mentioned as owned by Dr. Hall, was erected in 1841 at Twin Islands rapids. This ran for five years, when the lumbering interests became paramount, and as the dam interfered with the passage of logs it was removed. In 1845 another mill was built. The two mills now remaining are a pulp-mill at the Michigan abutment of the lower dam and a flouring-mill at its Wisconsin abutment. The head averages 7 feet, but sometimes the water of Green bay rises from 6 inches to 1 foot on their wheels. The pulp-mill belongs to the Marinette Paper Company, which, when visited in December, 1880, was expecting to erect an extensive addition in the succeeding summer for a paper-mill. There is much spruce and poplar along the river for wood-pulp, and the company also was thinking of logging the wood down the river as the lumbermen do. The good quality of wood costs $6 per cord, delivered in Marinette; but by logging they can probably obtain it much cheaper. The better quality of wood is used for the manufacture of fine paper. For common paper they use sawdust, ends, etc., sawed into pieces. The pulp-mill uses 670 horse-power, but they expected to use a total of 1,000 horse-power when the paper-mill was built. The flouring-mill, upon the south bank, has wheels for about 150 horse-power. It will be seen that with the improvements contemplated the low-water power at the lower dam is already taken up.

TRIBUTARIES OF THE MENOMINEE.

TABLE OF LENGTHS, DRAINAGE, AREAS, LOW-WATER DISCHARGES, AND POWER OF THE TRIBUTARIES OF THE MENOMINEE RIVER.

Name.	Length.	Drainage area.	Amount of yearly precipitation.	Estimated total volume of precipitation per second.	Ratio of low-water discharge of stream to total volume of precipitation.	Estimated ordinary low-water discharge of stream per second.	Theoretical horse-power under 10 feet head.
	Miles.	*Sq. miles.*	*Inches.*	*Cubic feet.*	*Per cent.*	*Cubic feet.*	
Bois Brulé river, including the Mequacumecum	42	1,013	35	2,612	17.8	465	528
Michigamme river	72	756	35	1,949	17.8	347	391
Pine river	53	586	35	1,511	17.8	269	305
Sturgeon river	50	409	35	1,055	17.8	188	214
Pembinebemon river	23	163	35	420	17.8	75	85
Pike river	43	292	35	755	17.8	134	152
Little Cedar river	32	149	35	384	17.8	68	77

It will be noticed that, in mentioning these streams in the order of their occurrence in passing down the Menominee, we have also given the order of their drainage areas, the largest being farthest up. There is only one exception, viz: in the case of the Pike and the Pembinebemon rivers. Of course there is no significance in this, as many small streams have been entirely omitted from the table; but one important deduction arises, which is that the tendency is to make the volume of the Menominee at its upper waters more nearly equal to that at its mouth. The total power of the stream would be very different from what it now is if the Bois Brulé, Michigamme, etc., entered near its mouth.

The Bois Brulé and the Michigamme rivers, by their junction, are considered to form the Menominee. The Mequacumecum river is called a tributary of the Bois Brulé, although its drainage area is nearly double that of the latter stream.

Bois Brulé river.—This is equivalent in English to Burnt Wood river, but by the Indians it was called Wisacodé. It runs between Wisconsin and Michigan. The extreme length, measured on the map, is 42 miles; the drainage area, including the 635 square miles tributary to the Mequacumecum, is 1,013 square miles. Its ordinary low-water power at the mouth under a head of 10 feet is estimated to be 528 theoretical horse-power. The extreme headwaters of the river cannot be very far from 900 feet above lake Michigan. At the mouth the Bois Brulé averages 180 to 200 feet wide. The bed of the river is mostly gravel and bowlders of the drift, and on this account the descent of the river, which is large, is not concentrated in vertical falls and sharp pitches, but is very uniformly distributed along the whole course, in either rapids or "strong water". It is said that there are scarcely 50 rods of slack water on the whole length of the stream. At the mouth is a vertical fall of 10 feet past an island. The banks of the river are usually steep, and in many places there are fine water-power sites. The

slope of the river is so uniform and so great that it is almost impossible to make a reservoir upon the stream sufficient in size for flushing down logs. The Menominee River Manufacturing Company has built one dam upon the river for that purpose.

THE MEQUACUMECUM RIVER.—This is the Indian way of saying Paint river. Although a nominal tributary of the Bois Brulé, it deserves separate mention. The length by map measurement is 54 miles; the drainage area is 635 square miles; and the estimated ordinary low-water power at the mouth, under 10 feet head, is 331 theoretical horse-power. The extreme headwaters are about 950 feet above the level of lake Michigan. The river is not so rapid as the Bois Brulé, but there are more vertical falls. The bed is largely gravel, as is the case with the Bois Brulé; but in places the ledge rock takes its place, and to this are due the falls. Three miles above the mouth is a descent of 20 feet in half a mile, divided between three pitches; above this for 4 miles is strong water. At this point is a dam, built by the manufacturing company, which backs the water up for 5 miles. At this point is Crystal falls, with 10 feet of nearly vertical descent. For the succeeding 13 miles up to Hemlock rapids there is strong water. Hemlock rapids are half a mile below the mouth of a river of that name, entering from the east. There is a fall of 16 feet in half a mile. The river flows in three channels, and the manufacturing company has blasted out the rocks from the main channel and turned all the water into that. A short distance above the mouth of Hemlock river there is a vertical fall of 8 feet.

It will be noticed that the river divides into three parts: one branch, the Hemlock river, springing from the northeast, another from the north, and a third draining the county west. These three branches cut through a series of ridges, and the result is on each stream a succession of broad basins and slow currents, with intervening rapids where it passes the ridges. At these places the streams are not over 100 feet wide, and this condition continues up to the sources of the river.

MICHIGAMME RIVER.—This stream is the largest tributary of the Menominee, properly speaking, for if we consider the Mequacumecum separate from the Bois Brulé the drainage area of the latter is less than one-half that of the Michigamme, whose basin is 756 square miles in extent. It is this stream which carries the drainage basin nearly across the upper peninsula of Michigan, the extreme sources being within 10 miles of the waters of lake Superior. The head of the river, however, is considered to be lake Michigamme, already mentioned as being the largest lake of the Menominee basin. The area is 6½ square miles, and the drainage area tributary to it 193 square miles, and if it is feasible to increase the reservoir capacity of this lake by a dam across the outlet it would exert an appreciable effect upon the steadiness of the stream below. The length of the river to the extreme sources is 72 miles (map measurement); to lake Michigamme, 51 miles. The ordinary low-stage power at the mouth, under 10 feet head, is estimated to be 391 theoretical horse-power, and the average width at the mouth is 250 feet and at the head 80 feet. Lake Michigamme is 980 feet above lake Michigan. There are several prominent falls and rapids on the river, and all the falls are over rock ledges, with rocky banks. About 1,300 feet from the mouth is a perpendicular fall of 30 feet, with steep, rocky banks. Four miles from the mouth is another vertical fall of 6 feet. Fifteen miles from the mouth, and about 3 miles below the mouth of Deer river, is a vertical fall of 10 feet over a rocky ledge. Three miles above the mouth of Deer river Fence or Michigan river enters, and between these is a flood-wood jam, caused by an island. This jam backs the water up somewhat. There is as yet no lumbering done so far up in the Menominee basin. Six miles above Fence river is Long Carry rapids, 1¾ miles long, with about 40 feet fall. Next there is a fall and rapid 3 miles below Republic mine, three-quarters of a mile long, with about 20 feet fall. Lake Michigamme is 8 miles above this place.

PINE RIVER.—This is the largest tributary of the Menominee lying wholly in Wisconsin, its length, measured along the general course, being 53 miles to the extreme sources. The drainage area is 586 square miles, and the estimated ordinary low-water power at the mouth, under 10 feet head, is 305 theoretical horse-power. For the first half a mile from the mouth the current is very rapid; in the next 12 or 13 miles the fall is comparatively slight, and the current moderate; and in the next 3 miles there are two falls of 8 feet each, 1,000 feet apart, half a mile of "strong water", succeeded by another fall of 12 feet; then, half a mile above, a fall of 40 feet. Sixty feet above this is a dam belonging to the Menominee River Manufacturing Company, used now for flushing down logs, and two miles up is the mouth of Poplar river. The lumbering only extends 6 miles above that.

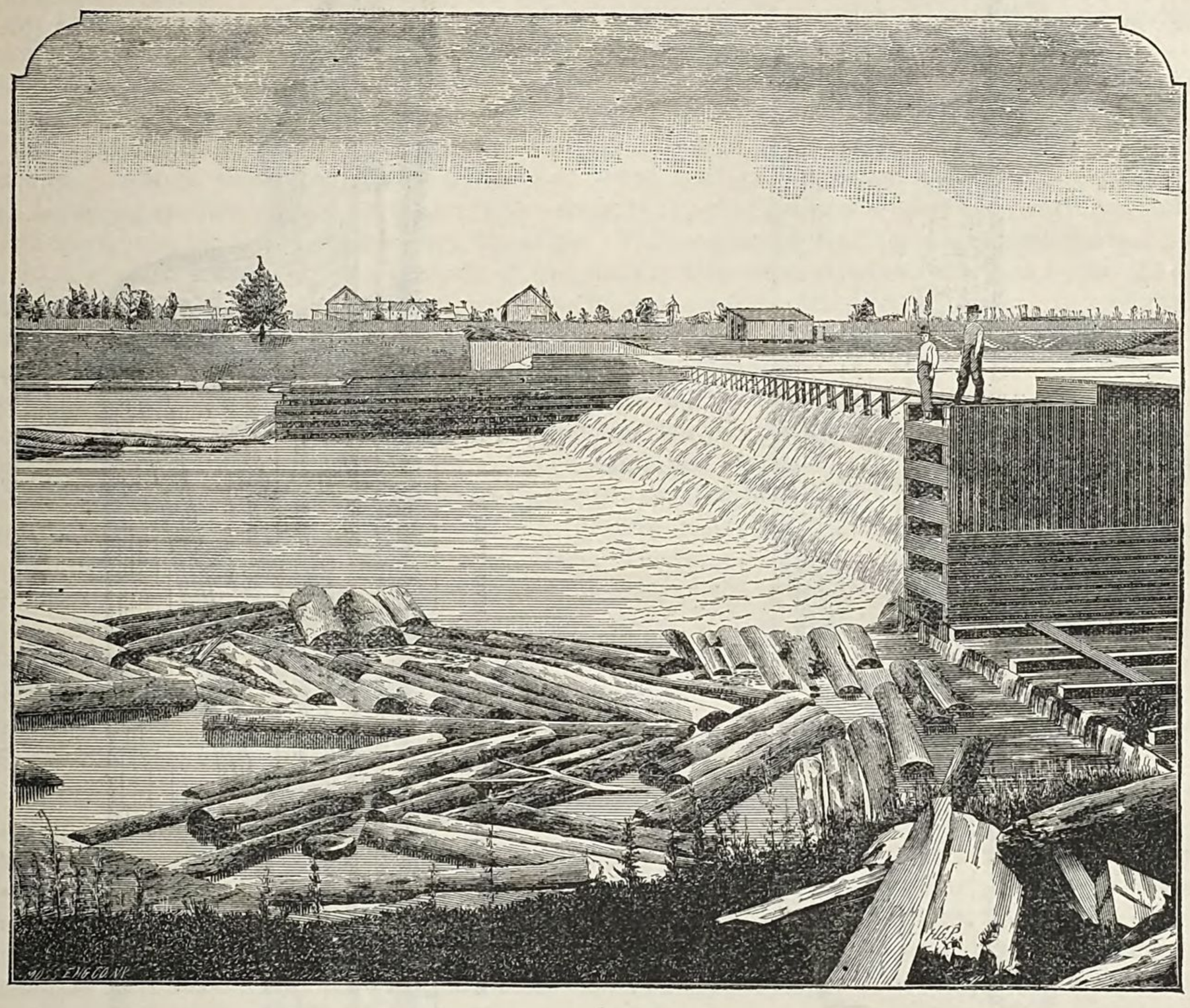
STURGEON RIVER.—The basin of this river is in Michigan, and its length (map measurement) to the extreme sources is 50 miles. The area drained is 409 square miles, and the power, under 10 feet head, at an ordinary low stage of the water is 188 theoretical horse-power. The average width at the mouth is 100 feet. The general course is south-southwest, nearly at right angles with the general slope of the country, and hence the fall of the river is comparatively slight. Ten miles above the mouth is a descent of 16 feet in three pitches.

As is the case with most of the streams flowing southward on the west side of lake Michigan, the river flows near the eastern limit of its drainage basin. This is, in all probability, due to the general southeast inclination of the country. Three-quarters of a mile above the falls is a dam belonging to the Menominee River Manufacturing Company.

All the lower tributaries are small and of less importance than the ones described. The largest is Pike river, in Wisconsin. The length to its sources is 43 miles, and the ordinary low-water power, under 10 feet head, at the mouth is 152 theoretical horse-power.

DAMS UPON THE MENOMINEE RIVER.

All dams on the river and its branches are owned by the Menominee River Manufacturing Company, which uses them for the lumber interests. Those upon the upper waters are for the purpose of making reservoirs, wherewith



LOWER DAM ON THE MENOMINEE RIVER AT ITS MOUTH.

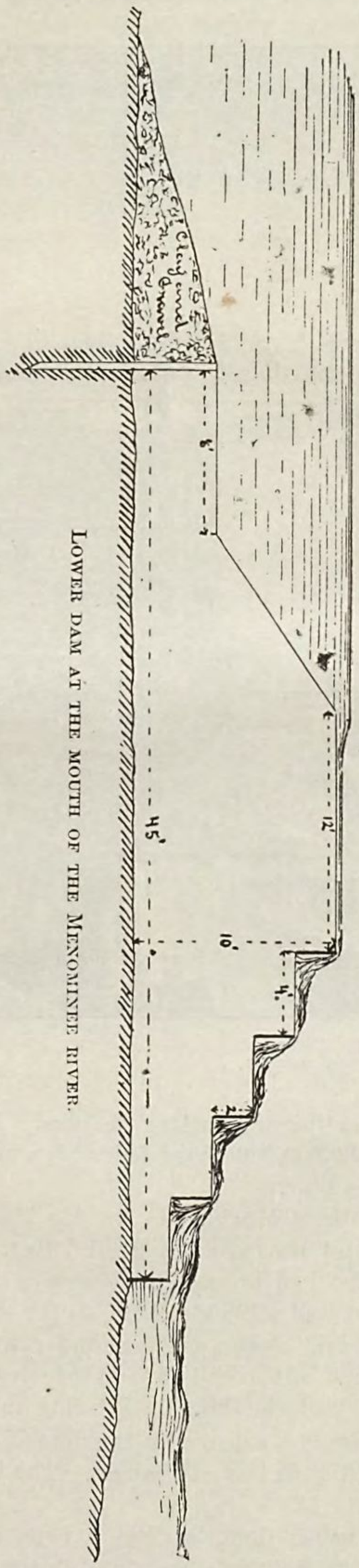
to flush logs down stream. The three dams at the foot are used for collecting and sorting the logs. The upper dam of those three forms a reservoir 5 miles long, and is capable of storing 300,000,000 board feet of lumber. The other two are chiefly as a security, to hold the logs in case the first dam gives way.

UPPER DAM.—The upper dam, called the Bently dam, is 1 mile above Marinette. It is a timber-crib dam, with a covering of spars. The length is 557 feet, the height 9 feet, and the average head 7 feet. The dam is arched up stream with a total rise of 10 feet, and cost $10,000. The bed is smooth limestone rock, and the structure is a continuous crib-work of round timbers, with a vertical face, and a back sloping to the toe of the dam. The base is about 30 feet broad. On the crib-work are hewed spars, laid close together, and running down to the river bed. The lower timbers are all bolted to the bed-rock by 1¼-inch iron drift-bolts, let into drilled holes, and fastened by wedges previously placed in their split ends. Upon the back of the dam is laid clay and gravel. At the face is a kind of apron, built of a low crib-work, planked over. There is a runway in the dam 75 feet wide and 1½ feet above the bed of the pond for the passage of logs. This is faced with hewed timbers. The logs glide over the apron just described.

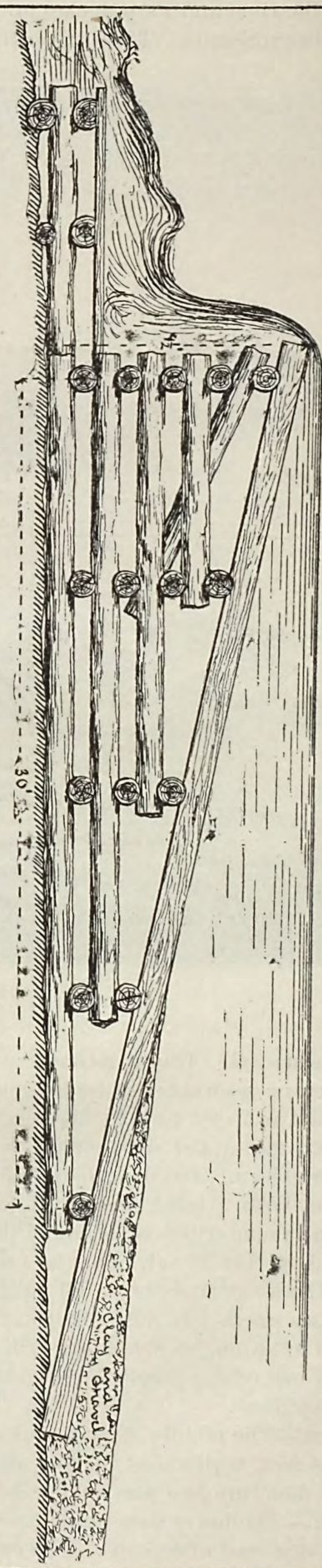
MIDDLE DAM.—The middle dam is similar in construction to the upper dam, but has a head of only 5 feet. The length is 644 feet, with about 10 feet rise of arch, and the cost was $8,000. An island in the center of the river divides the dam into two parts. The bed is limestone rock.

LOWER DAM.—The lower dam is the finest one on the river. It was built by Mr. H. A. Dow, of Minneapolis, in the year 1880, at a cost of $16,500. The construction is a timber crib-work. The dam is straight, 700 feet long and 9½ feet high. There is a runway near the center, extending below the dam about 120 feet, for the passage of logs, and there are eight sluice-gates. The bed of the river at that point is loose rock, clay, and gravel. Mr. Dow

had no drawings of the dam, and the description, dimensions of the cross-section, etc., were entirely obtained from an interview with him. The timber used is pine. The lower course is of logs, and the others of sawed timbers 12



LOWER DAM AT THE MOUTH OF THE MENOMINEE RIVER.



UPPER DAM AT THE MOUTH OF THE MENOMINEE RIVER.

by 12 inches in size. The planks are 3 inches thick. The cross-section is given. The front consists of a series of four steps, with 2 feet rise and 4 feet tread. The crest of the dam is horizontal for a width of 12 feet. The

back slopes down to 2 or 4 feet above the bed, where there is a horizontal bench, 8 feet broad. This is terminated by a vertical back to the river bed. The base is 45 feet wide. The whole dam is planked over, and at the back are sheeting piles, 3 inches thick, which were driven down into the bed and spiked against the outer timbers. Behind these clay and gravel were filled in. The water runs over the crest of the dam and falls down over the succession of steps. There is no apron below the dam. The runway is a crib-work of squared timbers, faced with the same kind of timbers, close laid. The rush of the current sends the logs through this with tremendous force. The abutments are built of timber cribs. No coffer-dam was used in the construction of this dam.

METHOD OF BUILDING.—The method employed was to build the cribs over their proper positions and sink them. Starting from the Wisconsin bank, four logs were floated down into position and held there, parallel with each other and 8 feet apart, with their lengths in the direction of the current. These covered an area 45 feet long and 32 feet wide. Across these was placed a course of sawed timbers. Another section, entirely similar, was floated down adjoining the first toward the center of the river, but leaving a space of 8 feet between them, and across these the crib-work was built, locking one with the other. This process of floating in the sections and building up the crib-work was continued until the position of the runway was reached, which was then built. In sinking the cribs enough of the sections in the crib-work would be floored, so that when filled with stone the weight would suffice to carry the structure down to the bed, and the other sections were left open. When the cribs were sunk in position the open sections were filled with stone, which filled up the inequalities in the bed under the crib and gave a uniform bearing to the lower course of timbers. After completing the runway a crib 32 feet long was built next to it on the Michigan side, and then a space of 32 feet was left for the passage of the water. The process of building the sections and crib-work above them was then continued to the Michigan shore. The heavy body of water which now passed through the space of 32 feet left open scoured the bed out to a considerable extent before it was closed. The method of closing was to make an immense trap-door, with a very strong frame, hung on a horizontal axis, and at the proper time this was let down. The force of the current immediately forced it shut against the crib-work on each side, and loads of gravel, hay, etc., held in readiness, were thrown in, and in two hours from the time of starting the opening was closed. Back of this trap-door the crib-work was built up and the dam completed.

There are several dams upon the upper tributaries of the Menominee, all of spar construction: and one on the Bois Brulé, 390 feet long, with two gates, each 9 feet wide: and one on the Mequacumecum, 375 feet long, with five gates, one 9 feet wide and four 7 feet wide. The Sturgeon and the Pine rivers have each a spar dam also.

MILWAUKEE, SHEBOYGAN, AND MANITOWOC RIVERS.

NATURE OF THE DRAINAGE AREA.—The water-shed separating the lake Winnebago basin from the streams flowing direct into lake Michigan is almost at the verge of the line of cliffs overlooking the Green bay and lake Winnebago valley. The Kettle range, a medial moraine of the glaciers already alluded to, does not act as a divide, but the larger streams find their way through it. The water-shed averages 300 feet above lake Michigan, and all this fall in the land takes place in a distance of about 30 miles. Toward the north the water-shed narrows to 10 or 15 miles wide, and at the southern end of the lake it is hardly more than 5 miles across. In the section about lake Winnebago, then, the drainage basins of the streams must be the largest, and it is there that the chief streams of the division are located. These are the Milwaukee, Sheboygan, and Manitowoc rivers. The lengths of these, measured along their general courses on a map of large scale, are, respectively, 66, 45, and 42 miles. The headwaters of the Milwaukee are about 500 feet, of the Sheboygan 360 feet, and of the Manitowoc 350 feet above lake Michigan; hence the average fall per mile of each stream is approximately as follows: Milwaukee, 7.6 feet; Sheboygan, 7.9 feet; and Manitowoc, 8.3 feet. These results are probably greater than the truth, because in estimating the lengths of the streams their general courses only were taken. This fall, of course, gives rise to many water-powers, and, as the country is already settled to a large extent, these water-powers are improved in part, but the greater portion is yet lying idle. From the statistical returns for the census of 1880 these data are obtained for the main streams. The returns from special agents on woolen-mills, cotton factories, and other special industries were not yet received at Washington at the writing of this report, and hence the accounts may be slightly too small for these streams; but the error cannot be great, as the bulk of the power is used in flouring- and grist-mills. It must be borne in mind, then, that the data given cannot be considered exact.

MILWAUKEE RIVER.

Number of flouring- and grist-mills		13
Total power used by these	horse-power	775
Number of saw-mills		6
Total power used by these	horse-power	122
Miscellaneous industries		5
Total power used by these	horse-power	75
Total power used on the river	do	972
Average power to each industry	do	40.5
Average head to each industry	feet	10.2
Maximum power used in one industry (flouring)	horse-power	145
Maximum head employed on the river	feet	24

SHEBOYGAN RIVER.

Number of flouring- and grist-mills		7
Total power used by these	horse-power	269
Miscellaneous		3
Total power used by these	horse-power	150
Total power used on the river	do	419
Average power to each industry	do	41.9
Average head to each industry	feet	12.4
Maximum power used in one industry (wooden packing-boxes)	horse-power	90
Maximum head employed on the river	feet	17

MANITOWOC RIVER.

Number of flouring- and grist-mills		6
Total power used by these	horse-power	174
Number of saw-mills		5
Total power used by these	horse-power	108
Total power used on the river	do	282
Average power to each industry	do	25.6
Average head to each industry	feet	9.8
Maximum power used by one industry (flouring)	horse-power	54
Maximum head employed on the river	feet	27

ESTIMATED POWER.—As near as can be estimated from data given and the comparison of the drainage-basins, the ordinary low-water power under 10 feet head along the lower portions of the river is, approximately: Milwaukee river, 250 theoretical horse-power; Sheboygan river, 220 theoretical horse-power; Manitowoc river, 165 theoretical horse-power. These figures can only be considered as approximate results.

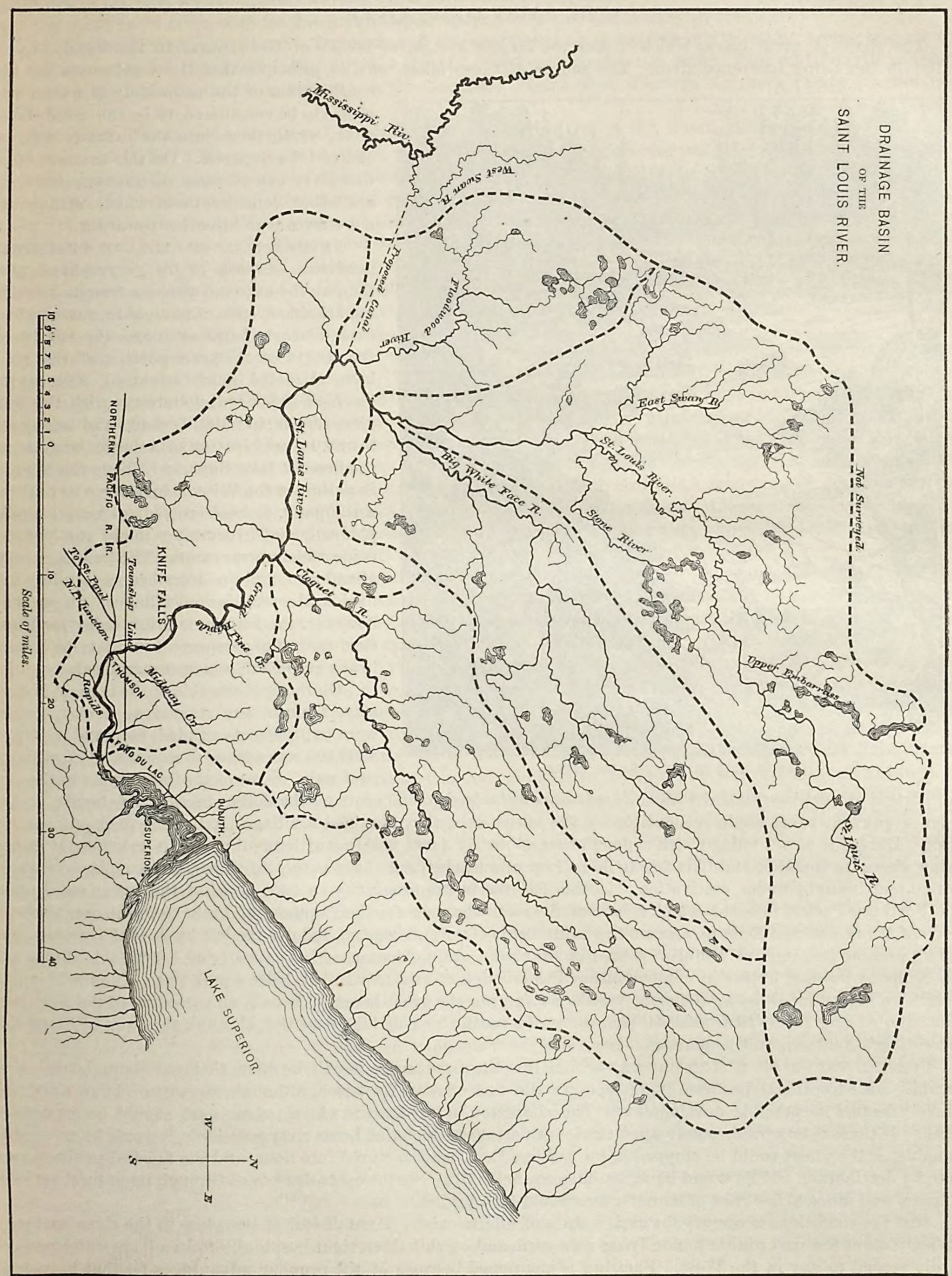
PECULIARITY OF THE MILWAUKEE RIVER.—It will be noticed that the course of the Milwaukee river is east in northern Ozaukee county until within 9 miles of lake Michigan, when it suddenly turns south and flows parallel with the lake above 30 miles to Milwaukee. Professor Chamberlain, in the geological report of this region, states that the river emptied into the lake at northern Ozaukee county, when the lake level was higher than now, at the time of the deposit of the lower red clay. The action of the waves threw up a beach line in front of the river mouth, and caused this to travel south in the endeavor of the water to force an outlet. Thus the river for the last 30 miles of its course flows behind an old lake beach. A similar case has been pointed out in the report on the Red River of the North, as occurring where the Otter Tail river empties into Otter Tail lake. Pike river and East Twin river, which empty at the west shore of lake Michigan, are also considered to have experienced similar conditions.

GENERAL REMARKS UPON RIVERS OF THE WESTERN PORTION OF LAKE SUPERIOR.

The streams tributary to western lake Superior are not of large size. The Saint Louis river, with a basin of 3,000 square miles, may perhaps be considered an exception, but it far exceeds any of its neighbors, and is claimed to be the second river of the entire lake in size.

What the rivers of the western part of lake Superior lose in volume they make up, however, in fall, and to a certain extent this is an equivalent in water-power. The water-shed is near the lake on both sides, but it is also elevated 1,000 feet or more above the lake level, and, as a consequence, the streams are very rapid. This characteristic feature of the lake Superior streams is most strongly exemplified on the north shore, where for a long distance the water-shed is at an average distance of 8 or 9 miles from the lake, and the streams go rushing down a descent that must be nearly 1,000 feet. The rock of the north shore is largely igneous and very hard. Many falls and rapids crowd the water-courses, and often right at its mouth a stream will take a final leap. This is the case with the Pigeon river, which forms part of the boundary between Minnesota and the British possessions, and is one of the largest of these north-shore streams. It is a portion of the water system connecting the Lake of the Woods, Rainy lake, and innumerable smaller bodies of water with lake Superior. The outlets of these lakes are so undecided that it is extremely difficult to determine just what are the boundaries of its drainage basin.

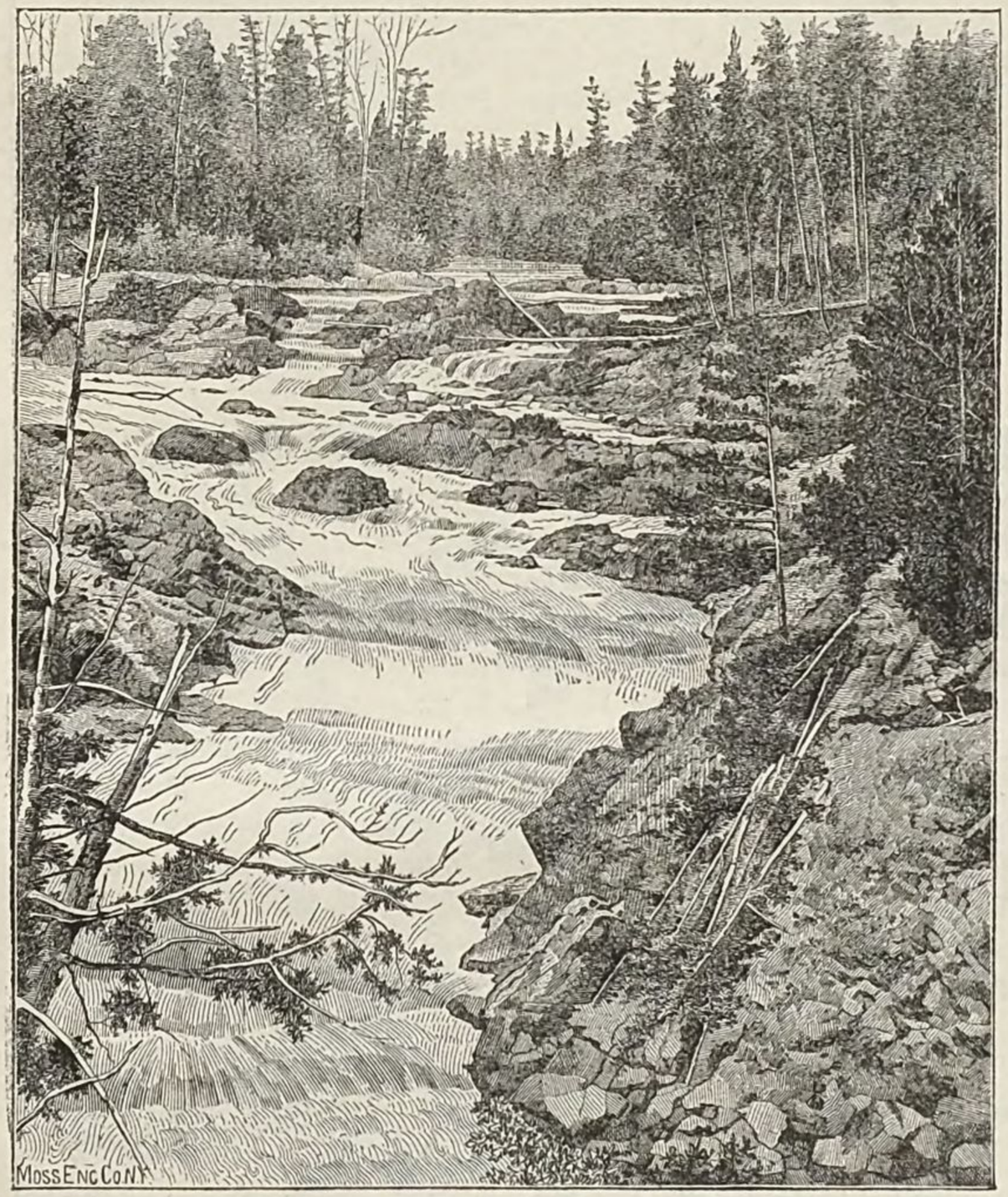
Although there is an annual precipitation of 30 to 34 inches upon this region, and an enormous aggregate of water-power, yet the country is so inaccessible and little improved that the power is of little value except in particular localities. With the Saint Louis river, at the extreme western end of the lake, the case is different, and as peculiar circumstances surround that stream special attention will now be given to it. Succeeding the report on the Saint Louis river are some remarks on the south shore of lake Superior and its water-powers.


DRAINAGE BASIN
OF THE
SAINT LOUIS RIVER.
Mississippi Riv.
West Swan R.
Proposed Canal
Floodwood River
East Swan R.
St. Louis River
Big White Face R.
Not Surveyed.
St. Louis River
Stone River
Cloquet R.
Grand Rapids
Fine Cr.
Upper Embarrass
St. Louis R.
NORTHERN PACIFIC R. R.
To St. Paul
N. P. Junction
Township Line
KNIFE FALLS
THOMSON
Rapids
Midway Cr.
FOND DU LAC
DULUTH.
SUPERIOR.
LAKE SUPERIOR.
Scale of miles.
0 1 2 3 4 5 6 7 8 9 10
10 20 30 40
N.
W.
E.
S.

83

THE SAINT LOUIS RIVER.

The chain of great lakes, which makes the largest system of bodies of fresh water in the world, has its outlet in the Saint Lawrence river. The source of these lakes, on the principle that the headwaters are the continuation of the main body of water, may properly be considered to be the Saint Louis river, which flows into the extreme western end of lake Superior. On this account alone this river enjoys some distinction, but there are other considerations which with much more force turn attention toward it.



RAPIDS OF THE SAINT LOUIS RIVER.

IMPORTANCE OF ITS GEOGRAPHICAL POSITION.—Owing to its geographical position, at the extreme western terminus of the remarkable system of navigable waters which extend nearly half-way across the continent, the shores of the lower portion of the river have attracted much attention, and capital has been expended, not always with the happiest results, in building docks and laying out towns, in anticipation of a large business at the head of lake Superior. Thus the town of Superior, on the Wisconsin shore, was built by a company, houses erected, extensive docks planned, and everything made ready for a trade which never came. The buildings were abandoned, and are described as standing idle in this almost deserted village. At present, however, the horizon is brightening for Superior, and the prospects are that its former hopes may be in a measure realized.

On the opposite side of the lake, in Minnesota, Duluth was started as a city, houses were built, streets graded, etc., and a debt of $400,000 was assumed, which made it a bankrupt city. Some of the inhabitants in the central portion of the place settled with the creditors on the basis of 25 cents on the dollar, issuing new bonds, and in order to prevent being made responsible for the entire debt they obtained a village charter for their part of the town. Duluth is now a village with a population of nearly 3,000, and, notwithstanding all its reverses, it is fast rising above its troubles, and bids fair to be an important point, especially as the Northwest is becoming so rapidly settled and brought under cultivation. In this lies the future prosperity as lake ports of the towns mentioned. The Northern Pacific railroad, which is one of the main channels for the shipment of grain from the great wheat-fields of Minnesota and Dakota, crosses the Saint Louis river at Thomson, follows the left bank of the stream, and has its present terminus at Duluth. There is situated a grain elevator, with a capacity of 1,000,000 bushels, and the company owning it has in contemplation the erection of two more of at least equal size. These will make Duluth an important shipping point for vessels navigating the great lakes. There is an extension of the Northern Pacific now being surveyed which will pass along the south shore of lake Superior, through the town of Superior, and through Ashland, on Chequamegon bay.

SPECIAL VALUE OF WATER-POWER.—From the above remarks it will be seen that the Saint Louis river occupies an exceptional position, lying right in the line of a traffic which, although already of large size, has scarcely begun its possible development. The character of the freight which passes east should be especially noted. If there is any water-power upon the lower portion of the Saint Louis river accessible, it would be especially valuable, as the wheat could be stopped in its passage East, manufactured into flour, and the finished product sent on to its destination. Mills would have the immense field of the Northwest to draw from through its natural arteries of trade, and unusual facilities of manufacture would be afforded.

Just the conditions necessary for such a state of affairs exist. The railroad passes close to the river, carrying the harvests of the vast prairie region lying westward, and on this river, right beside the railroad, are water-powers hardly second to any in the West. Flouring is mentioned because of the peculiar advantages for that branch of manufacture, but undoubtedly other forms of industry could be successfully prosecuted. For example, large

quantities of material for the manufacture of wood pulp could be obtained. In view of these facts, all must admit that the Saint Louis river, with its fine undeveloped water-powers, is well worthy of attention.

TRANSPORTATION FACILITIES.—The means of transportation at the mouth of the Saint Louis river are the natural waterway of the great lakes to the east, the Northern Pacific and Saint Paul and Duluth railroads connecting those places, the latter running on the Northern Pacific track from the Northern Pacific junction east to Duluth.

PROPOSED CANAL.—As mentioned in treating of the Red River of the North, there is a desire among the inhabitants of northern Minnesota to establish a canal connecting lake Superior with the Red River of the North. The real object of the majority of the advocates of this scheme appears to be to have some means whereby to hold the railroads in check and keep down freight rates to a proper limit. With this canal they can effect that object. As one of them remarked, "The farmers of the Red River valley do not care if only ten boat-loads of grain pass through the canal in a season." They would have at hand an agent, which, like the governor controlling the engine, will regulate the freight charges. However, notwithstanding that the canal would be closed during the winter months, it seems possible that it would be of value in itself as a practicable water-route. In the report of a committee on the subject the statement is made that, used as a freight route, it would result in a saving of $1,000,000 yearly to the Red River valley alone.

There has been no regular survey as yet, although at one time a bill making an appropriation for this object was introduced in the United States Senate. The route is considered an eminently practicable one to construct, and is roughly estimated to cost $4,000,000. The plan is to run up the Saint Louis river to Silver Creek, then pass along the left bank of the river 4 miles, overcoming the ascent by a canal with thirty-one locks, and at Midway creek once more enter the Saint Louis river, and follow the stream to the mouth of Floodwood river. There a canal 14 miles long would be cut northwest across the divide to the West Swan river. Entering the Mississippi, the route would run up stream, crossing from Turtle lake into the source of the Red Lake river, and so down that stream to the Red River of the North at Grand Forks, from whence there are navigable waters north and south. This canal would be of undoubted benefit to Duluth, and to the water-power interests already indicated on the Saint Louis river. Its construction is a matter for the future to decide.

The country about the Saint Louis river must yet be classed among the undeveloped lands of the Northwest. It is true that in the immediate vicinity of its mouth civilization has made its mark, but the river flows from a forest-covered country, scarcely yet disturbed. The deer yet roam its banks, and in the winter of 1880–'81 the moose frequented the upper waters in considerable numbers.

LUMBER INTERESTS.—The heavy pine growth of ages still covers the region to the northward of Duluth. There are saw-mills at Knife Falls, which, by a branch road to the Northern Pacific, ship considerable lumber, but they have not made much inroad upon the timber north of them, and it is estimated that 10,000,000,000 board feet of the finest kind of pine are awaiting the ax and the saw. Until recently there has been no demand for this timber. The Minneapolis market could undersell it in the south, and Wisconsin and Michigan would take the Chicago trade. With the rapid settlement of the West a demand is springing up in Dakota and western Minnesota which the Saint Louis region can successfully supply, and a great activity in the lumber trade of that section may be confidently looked for. Already have lumber companies sent explorers along the streams of the Saint Louis basin spying out the land. There is a Saint Louis River Improvement Company, Mr. W. L. Benning, of Saint Paul, president, formed for the purpose of clearing out the river and systematizing the driving of logs. This company has done considerable blasting at the rapids below Thomson.

CHARACTER OF THE COUNTRY.—The country south of the Saint Louis river is rather poor. The soil is to a great extent light and sandy, and is covered with a growth of timber of only medium quality, from which the best pine on the streams of the Saint Croix has been already cut. The region lying west of the river is also poor as a general thing. It is the same drift region in which the headwaters of the Mississippi run. Tamarack swamps, low meadows, and sandy ridges are the prominent features in the scenery. The western and northern tributaries run principally in this region, but the eastern branches of the river rise in the rocky section which characterizes the north shore of lake Superior. This shore rises in places in immense rocky cliffs sheer from the water's edge; in others it is a rugged slope; but everywhere that vegetation can gain a foothold it is covered down to the surface of the lake with a dense growth, and explorers say it is but a step from the wide expanse of sunlit water to the gloom and quiet of a deep forest. In passing to the lake the streams of the north shore of lake Superior are all rapid, with many heavy falls. It is the continuation of this rocky belt southwest in Minnesota which forms the rapids of the Saint Louis, about to engage our attention.

UPPER AND LOWER SECTIONS.—The Saint Louis river runs through two sections of country, different in geological age and in character, and hence changing the nature of the stream to a very noticeable extent. Above the mouth of the Floodwood river the basin lies largely in a region receiving all its characteristics from the comparatively recent glacial age; below that the course of the river is over the rocks of the earliest geological times of which we have definite knowledge.

In the upper section the land is level or elevated in ridges; the soil, sand, clay, and gravel, and the streams are

gentle in their flow over sand and gravel beds, with occasional rapids at accumulations of bowlders. In the lower section the country is rugged, and the hard igneous and metamorphic rocks, resisting the erosion of the stream, cause the river to foam in angry leaps and rapids in its descent to lake Superior.

ROCK OF THE LOWER SECTION.—The country through which the river runs near its mouth has been the scene of very violent action. Igneous rock was thrown out, breaking and upheaving the rocks previously formed, and to some extent changing their lithological character. Thus there is little uniformity in the occurrence of the different kinds of rock. Gabbro, an igneous rock, called granite at Duluth, but incorrectly so, is intruded, tilting the magnesian and argillaceous slates and the red sandstone, believed to be the equivalent of the Potsdam sandstone in the east, and in places actually fusing and converting them into a variety of red granite. This unevenness of the strata and the presence of dikes of igneous rock give a very wild character to the rapids of the Saint Louis river.

The rock about Duluth possesses considerable value as building material. This is specially true of the red sandstone, which is quarried in considerable quantity. It has somewhat the appearance of the brownstone quarried so extensively in New Jersey and Connecticut, but is not so rich in color, and has frequent white streaks running through it. The Huronian slates have been quarried for roofing purposes, but the enterprise was not successful, although the slate is of very fair quality. Recently (1881) new quarries have been opened in the state. The so-called granites of Duluth are also quarried for building purposes, but the stone has a poor cleavage, and is difficult to cut. The prospecting for iron ore in the region northeast of Duluth is probably caused by this rock, which is sometimes very rich with magnetite.

It is the opinion of the geologists who have explored that region that the country of the upper Saint Louis above the Floodwood river and about the Mississippi was once the bed of a lake long since drained. There is some fertile land, the deposit from this ancient lake. The water-shed between the Mississippi and the Saint Louis rivers runs for a portion of its course along a line of drift hills, and at Sandy lake the highest is 139 feet above the water. On the north the water-shed is determined by the Mesabi range of drift, the waters to the north of that running into the Rainy Lake system.

TRIBUTARIES.—A glance at the accompanying map will show that the basin under consideration is approximately oval in form, the major axis, lying parallel with the north shore of lake Superior, being about 80 miles long and the minor axis 50 miles. The main tributaries flow southwest. The Saint Louis itself runs southwest to the mouth of Floodwood river, then turns suddenly and flows in a generally southeast direction to lake Superior, intercepting the branch streams from the east.

The basins of the upper Saint Louis, the Big White Face, and the Cloquet rivers divide the total drainage basin approximately into three symmetrical portions, of which the Big White Face river occupies the middle one. The water-shed on the south has an average distance from lake Superior of about 8 miles, and all the streams which flow into the lake south of it are small. The tributaries on the west have little fall; those on the east are rapid in their upper portions, but when they strike the level and rolling region they, too, are moderate in their flow.

The chief tributaries, in the order of their occurrence from the source, are these:

Name.	Length (map measurement).	Drainage area.
	Miles.	*Square miles.*
Big White Face river	55	534
Floodwood river	34	257
Cloquet river	65	675

VOLUME OF THE SAINT LOUIS RIVER.—No accurate observations have been made of the flow of the Saint Louis river. On May 24, 1870, Mr. James B. Francis made, as he states, a rough observation of the flow at Thomson, which he found to be about 5,600 cubic feet per second. "The river was then evidently above the minimum flow." The ordinary low-water flow has formerly been taken at 2,000 cubic feet per second in making calculations on the water-power of the Saint Louis river, but this estimate was stated to be a very rough approximation. With no measurements to aid us, it is impossible to arrive at a close result, but the data at hand lead to the conclusion that 2,000 cubic feet per second is too high an estimate.

ESTIMATION OF FLOW FROM THE RAINFALL.—The Saint Louis basin is largely similar to the country about the upper Mississippi, on which regular gaugings have been made. The latter has more lakes, but about the Saint Louis river are many marshes, especially on the west, and on the east the forest growth is denser and evaporation less. From the sand ridges many fine springs feed the streams, and these have an important effect upon the permanency of the flow. The amount of annual precipitation at the headwaters of the Mississippi, used in the estimates for the reservoir system on that river, is 25 inches, while on the Saint Louis basin it averages nearer 30 inches. At Duluth it is 33 inches. It is thought safe to conclude that the discharge per square mile of drainage area on the Saint Louis will be that on the upper Mississippi, increased by an amount due to the greater precipitation about the former stream.

The following data have been obtained on the Mississippi:

Area of basin above Grand rapids, 3,636 square miles; discharge at a stage 0.4 foot below mean low water, 969 cubic feet per second. Hence, discharge per square mile of drainage area, 0.27 cubic foot per second.

Area of basin above Aitkin, 5,715 square miles; discharge at a stage 0.2 foot below mean low water, 1,743 cubic feet per second. Hence, discharge per square mile of drainage area, 0.305 cubic foot per second.

Because these gaugings were made when the river was slightly below an ordinary low stage, it is thought best to assume the ordinary low-water flow to be 0.34 cubic foot per second per square mile of drainage area.

From this, allowing for the greater rainfall, it is concluded to assume the flow per square mile from the Saint Louis basin to be 0.4 foot at ordinary low water. This would give a discharge at Thomson of 1,223 cubic feet per second. In the absence of measurements, it cannot be positively stated that this is correct, but it is the result arrived at after comparison with the neighboring stream, the Mississippi, on which actual measurements have been made. The theoretical power with this discharge under 10 feet head would be 1,388 horse-power. Throughout a large portion of the year, in all probability, the power would be at least double this.

Tributary to the Cloquet river are four or five lakes, with an area of from 3 to 4 square miles each, and upon the extreme upper waters of the Saint Louis is about the same lake surface; but, compared with the Mississippi and the Red River of the North drainage basins, the lake system of the Saint Louis is unimportant. If the Saint Louis were an eastern river, however, it would be considered to be well supplied with lakes. It is very probable that if the water-power interest of the stream warranted the expenditure extensive reservoirs could be made in the swamps among the ridges and the low-water flow be very greatly increased.

TABLE OF POWER OF THE SAINT LOUIS RIVER.

Place.	Distance from preceding station (map measurement).	Tributary area above station.	Estimated ordinary low-water discharge per second.	Resulting theoretical horse-power under 10 feet head.	Effective horse-power under 10 feet head, at 75 per cent.
	Inches.	*Sq. miles.*	*Cubic feet.*		
Above Big White Face	75	1,044	418	474	356
Mouth of Big White Face	0	1,578	631	716	537
Mouth of Floodwood	6	1,835	734	833	626
Mouth of Cloquet	18	2,834	1,136	1,286	965
Knife Falls	12	2,926	1,170	1,328	996
Thomson	7	3,058	1,223	1,388	1,041
Fond du Lac	10	3,106	1,242	1,410	1,058

One peculiarity of the Saint Louis river is that its descent is concentrated upon the lower waters, where the volume of flow is largest. This is a very favorable condition for the water-power of the basin, as it concentrates the power which would otherwise be distributed in small streams. The upper portion of the Saint Louis is rather sluggish, but as the water nears the lake it increases its speed, until near the mouth it is a foaming torrent.

Above the Big White Face.—Rapids are infrequent near the headwaters, and when they occur are over accumulations of bowlders. The drift hills usually come close to the river on one side, while on the other a timbered bottom forms the shore. In places both banks are low and flat.

A few miles above the mouth of the Big White Face river is a locality where, according to report, a head of 20 feet can be made available by building a dam.

The drainage area tributary to the Saint Louis river above the Big White Face river is approximately 1,044 square miles. The region is not yet fully surveyed. The estimated ordinary low-water flow above the mouth of the Big White Face river is 418 cubic feet per second, which, under 10 feet head, would give 474 theoretical horse-power.

Big White Face to Floodwood river.—Below the mouth of the Big White Face river the drainage area is increased to 1,578 square miles, the estimated ordinary low-water flow to 631 cubic feet per second, and the resulting power, under 10 feet head, to 716 theoretical horse-power.

Floodwood to Cloquet river.—By the entrance of the Floodwood river from the west 6 miles below the area tributary to the Saint Louis river is increased to 1,835 square miles, the ordinary low-water flow to 734 cubic feet per second, and the theoretical power under 10 feet head to 833 horse-power. From the mouth of Floodwood river for the first 2 or 3 miles there is little fall, and for the following 6 miles there is a fall of about 40 feet. From there down to Cloquet rapids, near the mouth of the river of that name, there is little descent. These rapids consist of a descent of 5 feet in about 1,300 feet distance.

GRAND RAPIDS.—Four or five miles below begin Grand rapids. There the river falls 75 feet in 5 miles, averaging 500 feet in width.

The drainage area tributary to the river above these rapids is about 2,834 square miles, the estimated ordinary low-water flow 1,133 cubic feet per second, and the resulting theoretical power, under 10 feet head, 1,286 horse-power. The total theoretical power with the 75-feet fall is 9,645 horse-power. Half a mile below the foot of Grand rapids is a small descent called Pine rapids. From there down to Knife Falls the descent is slight.

KNIFE FALLS TO THOMSON.—At Knife Falls there is a series of pitches over sharp upturned strata of slate rock. From the effect upon the moccasins of the traders and Indians originated the name. In Dr. David D. Owen's report the falls are stated to amount to a descent of 20 feet. The rapids make the total descent much larger. The total fall from above Knife Falls to the township line, about 1 mile north of Thomson, a distance of about 4½ miles, is 154 feet.

The drainage area tributary to the river above Knife Falls is 2,926 square miles, the estimated ordinary low-water flow 1,170 cubic feet per second, and the resulting theoretical power, under 10 feet head, 1,328 horse-power. This would make the total power, with the 154 feet head, 20,451 theoretical horse-power.

RAPIDS OF THE SAINT LOUIS RIVER.

From Thomson down to the sandstone quarry just above the village of Fond du Lac occur the rapids of the Saint Louis, which place it in the front rank among the rivers of the West as a water-power stream. A descent of 456 feet is made from the township line, 1 mile north of Thomson, down to Fond du Lac. Just above the railroad at Thomson the river is forced through a channel about 60 feet wide, between perpendicular walls of rock some 30 feet in height. Immediately on passing under the railroad bridge the stream veers to the east and commences a series of the wildest leaps over upturned ledges of slate rock. The dip of the strata is down stream about 40 degrees, and, as shown in the view, a series of jagged pockets is formed. Filling one, the water foams over the crest and falls into the next below.

RAPIDS OF THE SAINT LOUIS.

The Northern Pacific railroad follows the course of the river, and in going to Duluth the view from the rear of the train is very beautiful. At Thomson the river bed is near the general level of the country, but as it descends hills 200 to 500 feet high rise above the water, covered with a wild growth of pine and other timber. Through deep gorges small branches find their way to the main stream, and down at the bottom of its valley is the river, now foaming over its rocky bed in rapids such as those just described, now making a graceful sweep of gentle water around a projecting slope. Dr. Owen, in his report, made many years ago, distinguishes four series of falls in the course of the rapids of the Saint Louis thus:

The lower falls are 3 or 4 miles above Fond du Lac, where the old portage trail began, and consist of a series of ten or eleven cascades, from 6 to 10 feet high, running obliquely across the channel. These occupy a total distance of half a mile. He estimates the entire fall to be 103 feet.

The second falls are 1½ miles above the first; and although the total descent is only 76 feet, yet they are far more imposing. Solid walls of rock rise 30 to 40 feet, and extend far into the stream, really making the river to run on its edge, as it were. In one place the channel is 40 feet, and in another only 25 feet wide, while above and below it is 600 to 450 feet across.

The third falls are a series of cascades, with a total descent of 45 feet.

The fourth falls are very similar to the second, and consist of five large pitches and many smaller ones. The total descent is a little over 100 feet.

It will be seen by Dr. Owen's report that there is great variety in the nature of the river at the rapids; but

it must not be supposed that the descent is confined to the falls, as grouped by him, with intervening still water. The river is more or less rapid all the way. In the contracted places, where the channel is deep and the velocity very great, it appears very small; but it averages 100 to 200 feet wide in the rapids, and at Fond du Lac spreads out into a stream several hundred feet wide, with a current of 4 miles per hour, and is navigable up to Fond du Lac.

The Saint Louis River Improvement Company, already alluded to, is engaged in building dams and reservoirs upon the upper section of the river for logging purposes, and has expended much work upon the Saint Louis rapids in blasting out the rocks, which would tear the logs into splinters. In high water the rocks are largely covered.

FALL AND POWER OF THE RAPIDS OF THE SAINT LOUIS.—It has been stated that the total fall from the township line north of Thomson down to Fond du Lac is 456 feet. Of this, 372 feet occur in the first 4 miles down to the mouth of Silver creek and 84 feet in the remaining 7 miles by river to Fond du Lac. Thus the heaviest fall of the stream is this 372 feet in 4 miles, an average of 93 feet per mile.

The drainage area tributary above Thomson is 3,058 square miles, and the estimated ordinary low-water flow is 1,223 cubic feet per second. Under 10 feet head this would give a theoretical power of 1,388 horse-power, and under the total head of 456 feet the theoretical power would be 63,293 horse-power. It was the opinion of Mr. James B. Francis that, while the total fall could not be available, undoubtedly three-fourths of it would be. Three-fourths of the fall is 342 feet, and this would give 47,469 theoretical horse-power at ordinary low water.

It was impracticable to make a complete observation of the lower portion of the river, but from what could be gathered by a hasty view and by conversation it seems that much the greater portion of the power is available. It is true that the river valley is wild and rocky in many places, but there are numerous localities suitable for the building of dams and canals, with limitless material near at hand, while access could be readily had to buildings stationed at the river. As to transportation facilities, enough has already been said to indicate the superior advantages afforded this water-power, with the navigation of the great lakes at its door and the railroad following the river.

WATER-POWER COMPANY.

The legal conditions of the water-power of the rapids of the Saint Louis in January, 1881, were these, as obtained from Mr. E. L. Craw, of Duluth:

For some time past a few capitalists, with Mr. Jay Cooke as the leader of the enterprise, have realized the future value of this power, and have lately obtained possession of it. For two years Mr. Craw was actively engaged in buying out the many former owners along the river, and when met had just received the last deed; so that the title is now clear to both banks of the stream from Fond du Lac to Knife Falls inclusive, a distance by river of about 17 miles. In January, 1881, the company was about to be incorporated, representing a capital of $3,000,000.

POWER OWNED BY THE COMPANY.—As may be estimated from the figures already given, the company own 610 feet fall. Of this, 154 feet are above the township line, 1 mile north of Thomson, and 456 feet from that line down to Fond du Lac. With the estimated ordinary low-water flow past Thomson of 1,223 cubic feet per second, the total theoretical power under 610 feet head is 84,668 horse-power, and, with an efficiency of 75 per cent., the available or effective power is 63,501 horse-power. Taking Mr. Francis' estimate that three-fourths of the fall could undoubtedly be utilized, the available head would then be 458 feet, the theoretical power 63,570 horse-power, and the effective power, with wheels giving an efficiency of 75 per cent., 47,678 horse-power. This is about 14,000 horse-power greater than the total effective power of the Lower Fox river in Wisconsin, and very nearly one-half the effective power available from the Mississippi river at Minneapolis under an efficiency of 75 per cent.

PROPOSED IMPROVEMENT.—The plan proposed by the company is eventually to build dams at different places along the river and utilize the power by canals extended along the banks. Mills would be located along these canals, and side-tracks run to them from the main railroad line. The chief industry toward which they must look for the success of their enterprise is the manufacture of flour.

About one-third of a mile above the railroad bridge Midway creek enters the river from the east. The plan is to throw a dam across the river a short distance below the mouth of Midway creek and back the water up into that stream. From Midway creek a canal will run past the village of Thomson, and, bending, follow along the railroad track, which will lie between it and the river. Mills will be stationed along this canal convenient to the railroad, with their tail-races tunneled out to the river. It is stated that 75 feet head of water can be obtained. Under this head the ordinary low-water power would be 10,410 theoretical horse-power. It is practicable to extend the canal about 5,000 feet along the river.

Mr. James B. Francis, in making some suggestions with relation to the improvement of the power, proposed that the canal should have a capacity of 1,500 cubic feet per second and a cross-sectional area of 500 square feet; that it should be 55 feet wide and 9 feet deep, with a mean velocity of 3 feet per second. The total depth, he states, should be 12 feet, to allow for ice.

RIVERS OF THE SOUTH SHORE OF LAKE SUPERIOR IN WISCONSIN.

This region derives some importance, and deserves consideration in this report, because of the intended extension of the Northern Pacific railroad east through its length. The country is yet a wilderness, but the time will come when, if there is anything to be developed, use will be made of it. It was in view of these facts that a trip was made on the Wisconsin Central railroad to Ashland, on Chequamagon bay (pronounced Shewamegon), to gain information concerning the water-power.

TOPOGRAPHY.—The water-shed runs near the lake, although not so close as on the north shore, previously alluded to, and is at an average distance of about 30 miles from the shore. On this account the streams are not large, the greatest, Bad river, having a drainage basin of 1,045 square miles. The average altitude of the water-shed is from 950 to 1,050 feet about the Red river, and 600 feet toward the end of the lake. It runs through a flat, swampy region, difficult to locate, and many of the tamarack swamps and lakes have two outlets—one into the rivers leading to the Mississippi, and the other toward lake Superior.

On a line from south to north about the Bad river the profile is this: From the water-shed line, in places 1,100 feet above the lake, the descent is very gradual to within about one-quarter of a mile of the Penokee iron range, when there is an ascent of 100 to 300 feet. From the crest of the Penokee range the descent is much more rapid for 100 to 300 feet to a ridgy section, which is elevated 500 or 600 feet above the lake. This terminates in what is called the Copper range, where there is a descent of 400 or 500 feet in about 3 miles. From there to the lake the descent is 100 to 200 feet, constituting the lowland area. At the western end of the lake the water-shed is about 600 feet above the lake. The descent is gradual, and then there is a gentle rise to the north for 1 or 2 miles to the Copper range, from 400 to 650 feet above the lake. From the ridgy country forming the Copper range there is a sudden descent of 300 or 400 feet, and from the foot of the range to the lake, a distance of from 5 to 10 miles, there is a gradual descent of from 100 to 250 feet.

ROCK AND SOIL.—The rock of this region belongs to the oldest formations of the globe. South of the Penokee iron range it is the old Laurentian base, which is the foundation for the superposition of the sedimentary rocks occurring further south in Wisconsin. Then comes the Huronian, of which the Penokee range is formed. It is made up of metamorphic rocks, consisting of schists, marbles, granites, etc., and contains extensive accumulations of magnetic iron ores. The name Penokee was derived from the Chippewa word *pewabic*, meaning iron, by the mistake of a printer. Succeeding the Huronian on the north is the Keweenaw system of rocks, a metamorphic system of later origin than the Huronian, according to the best authorities. This is the continuation of the Keweenaw Point ridge, and contains more or less copper. The Copper range belongs to the Keweenaw series, and north of this is the old red sandstone of lake Superior.

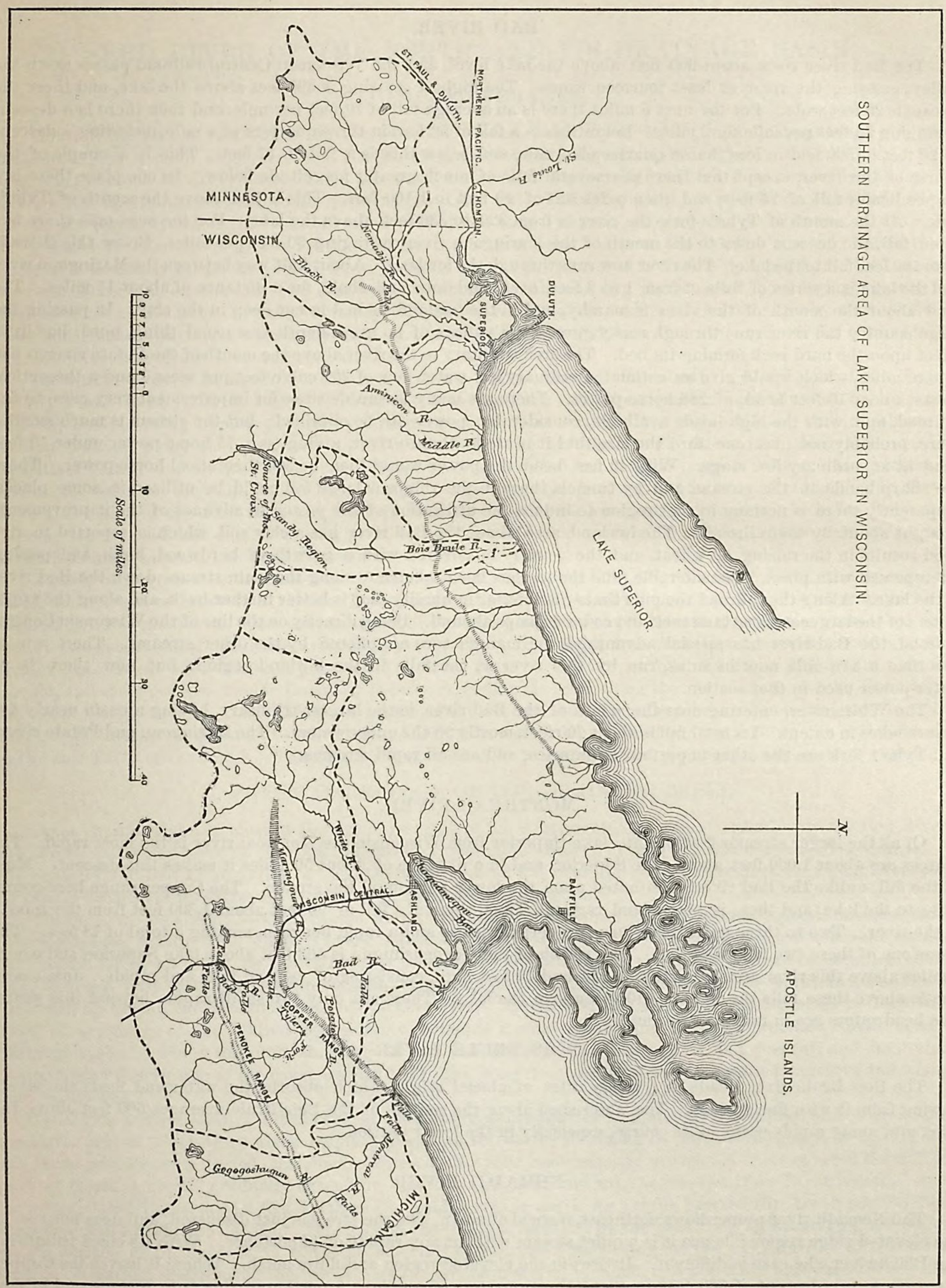
These rocks are very largely covered with glacial drift, and, especially in the section between the Copper range and the lake, with a heavy lacustrine clay deposit. There the streams have cut deep gorges in the clay, 25 to 100 feet in depth. There the Wisconsin Central railroad crosses the White river, a tributary of the Bad river, by a trestle 1,300 feet long and 100 feet high, called by the Indians the "Spider-web".

FLOW OF THE STREAMS.—The principal streams flowing into lake Superior from Wisconsin are these:

Name.	Drainage area.	Estimated ordinary low-water flow, per second.	Theoretical horse-power under 10 feet head.
	Square miles.	*Cubic feet.*	
Bad river	1,045	418	473
Nemadji river	439	176	200
Montreal river	284	114	129
Bois Brulé river	148	59	67

It is thought, by comparing with the neighboring streams, that the ordinary low-water flow approximates to 0.4 cubic foot per second per square mile of drainage area, for these reasons: The Upper Mississippi, with an annual precipitation of 25 inches, has about 0.34 cubic foot, and the Saint Louis, with a rainfall of about 30 inches, is estimated to have 0.4 cubic foot. The region now under discussion has an annual precipitation of from 30 to 35 inches, while it is not so retentive of moisture as the basins of the above-mentioned streams.

The streams given in the table would have little water-power were it not for their rapid descent to lake Superior. In passing through the Penokee and Copper ranges they are exceedingly rapid, and in many places are vertical falls.


SOUTHERN DRAINAGE AREA OF LAKE SUPERIOR IN WISCONSIN.
APOSTLE ISLANDS.
MINNESOTA.
WISCONSIN.
ST. PAUL & DULUTH.
NORTHERN PACIFIC.
THOMSON.
St. Louis R.
DULUTH.
SUPERIOR
Nemadji R.
Black R.
Amnicon R.
Middle R.
Source of the St. Croix.
Sandy Region
Bois Brule R.
LAKE SUPERIOR
Scale of miles.
0 10 20 30 40
N.
White R.
Marengo R.
WISCONSIN CENTRAL.
ASHLAND.
Chequamegon Bay
BAYFIELD
Bad R.
Falls
Potato R.
COPPER RANGE R.
Tyler's Fork
MENOKEE RANGE
Gogogoshugun R.
MICHIGAN

BAD RIVER.

The Bad river rises about 900 feet above the lake level, and the Wisconsin Central railroad passes down the valley, crossing the river at least fourteen times. The highest crossing is 895 feet above the lake, and there the stream is 20 feet wide. For the next 5 miles there is an average fall of 10 feet per mile, and then there is a descent averaging 25 feet per mile for 2 miles Below this is a fall of 52 feet in three-quarters of a mile, including a descent of 20 feet in 500 feet in less than a quarter of a mile, and below this is a fall of 17 feet. This is a sample of the course of the river, except that there are several falls of much greater magnitude below. In one place there is a perpendicular fall of 25 feet, and then a descent of 40 feet in 1,100 feet. This is just above the mouth of Tyler's fork. At the mouth of Tyler's fork the river is from 320 to 330 feet above the lake. For the next mile there is a rapid fall, the descent down to the mouth of the Maringoun river averaging 30 feet per mile. Below this there is 90 to 100 feet fall to the lake. The river now runs through the lowland. About half way between the Maringoun river and the lake is a series of falls of from 1 to 2 feet, over sandstone and shale, for a distance of about 1½ miles. The land about the mouth of the river is marshy, and in the lowland its bed is cut deep in the clay. In passing the ridge country the river runs through rocky gorges and valleys of no great depth as a usual thing, but it has little effect upon the hard rock forming its bed. The area tributary to the river above the mouth of the Potato river is 636 square miles, which would give an estimated ordinary low-water flow of 254 cubic feet per second and a theoretical power, under 10 feet head, of 288 horse-power. There are many favorable sites for improvement very close to the railroad, and, with the high heads available, considerable power can be obtained; but the stream is much smaller there, probably not over one-third the size that it is at the Potato river, giving, say, 75 horse-power under 10 feet head at an ordinary low stage. With 40 feet head the power would then be 300 theoretical horse-power. There are sharp bends in the stream, and by tunnels through the ridges a large fall could be utilized in some places. Apparently there is nothing in that region to induce the utilization of the power in advance of the improvements brought about by the railroads. The lowland area about the Bad river has a clay soil, which is reported to give good results in the raising of wheat, and the country is covered with a growth of hardwood, birch, and poplar, interspersed with pines. Considerable pine timber has been taken out along the main stream down the Bad river to the lake. Along the railroad the pine timber is inferior in quality, but is better further back, and along the upper waters of the larger streams tamarack and cedar swamps abound. Being directly on the line of the Wisconsin Central railroad, the Bad river has special advantages for manufacture not offered by the other streams. There was at one time a saw-mill, now in ruins, run by this river at the falls in the lowland region; but now there is no water-power used in that section.

The White river, entering near the mouth of the Bad river, is the largest tributary, having a basin nearly 400 square miles in extent. Its total fall is about 700 feet, mostly on the upper waters. The Maringoun and Potato rivers and Tyler's fork are the other important tributaries, and are all rapid streams.

MONTREAL RIVER.

Of all the larger streams flowing into lake Superior from Wisconsin the Montreal river is the most rapid. The sources are about 1,000 feet above lake Superior, and in a distance of about 50 miles it makes this descent. Most of the fall, unlike the Bad river, is situated upon the lower portion of the stream. The Copper range here comes close to the lake, and there is no lowland region. Thus, there is a fall of 90 feet about 1,300 feet from the mouth of the river. Two to three miles above are two vertical leaps and a rapid between, making a total of 78 feet. The lower one of these two falls is 40 feet. The mouth of the Gogogashugun is 503 feet above lake Superior, and about 4 miles above this river are three falls, 15, 35, and 25 feet high, consisting of vertical falls and rapids. Just about a mile above these falls the river is 910 feet above the lake. There are only two small rapids beyond this point. The headwaters are in tamarack swamps.

BOIS BRULÉ RIVER.

The Bois Brulé river heads in a sandy ridge of glacial origin, which absorbs the water and feeds the rivers flowing from it with fine springs. The water-shed along the sources of the Bois Brulé averages 600 feet above the lake, and many rapids occur in its course, especially in the lower portion.

NEMADJI RIVER.

The Nemadji river proper flows northeast, instead of north, like the streams just discussed, and does not rise in the elevated ridge region; hence it is a quiet stream without any rapids of importance. With its chief tributary, the Black river, the case is different. It rises in the elevated region and flows north. Where it leaves the Copper range there is a descent of 300 feet in about three-quarters of a mile. A portion of this is in a chute of 140 feet at an angle of 80 degrees and a fall of 50 to 60 feet at the foot.

RED RIVER OF THE NORTH AND ITS DRAINAGE BASIN.

GENERAL REMARKS.

COURSE OF THE RIVER.—Sixty miles east of the western boundary of Michigan, and about 9 miles north of latitude 47°, is a small sheet of water, 4 miles long and narrow, bent at right angles in the middle, to which is given the name of Elbow lake. From this runs a stream in a generally southern direction, called Otter Tail river, which finally discharges into the northeastern end of Otter Tail lake, about ten miles north of latitude 46° 30′.

At the opposite end of this lake, 40 miles east of the state line, and properly the continuation of Otter Tail river, starts the Red River of the North. Taking a west-southwest course to the border between Minnesota and Dakota, it suddenly turns sharp, and, flowing almost due north for about 190 miles by land, forms the boundary between Minnesota on the east and Dakota on the west; then, crossing the national boundary, it passes into Manitoba, losing its name in lake Winnipeg, but finally reaching the waters of the Atlantic by way of Nelson river and Hudson bay. Its waters first find the ocean in latitude 57°, four degrees north of the headwaters of the Columbia, one of our most northern streams.

PRODUCTION OF THE REGION.—The region of the United States lying about the Red River of the North is strictly a new country. Only within the past few years has the tide of emigration been directed to this region, and the land is being rapidly settled by foreigners of northern blood. It is eminently the land of wheat. In eastern Dakota, along the Northern Pacific railroad, are the vast Dalrymple farms, and along the immediate Red River valley, and up the valley of the Goose river, are raised remarkable crops of wheat. The winters are severe, the summers are mild, and growth is rapid. The warm air from the Japan current in the Pacific, flowing down the region of the Saskatchewan, spreads over the Northwest a softening influence, which forces back the piercing Arctic cold, and makes farming possible hundreds of miles north of Winnipeg. Even in winter, except in extraordinary seasons, the climate is comparatively mild.

TRANSPORTATION FACILITIES.—The local means of transportation are the Saint Paul, Minneapolis and Manitoba railroad to Saint Paul, the Northern Pacific railroad, and, in addition, for north and south transportation, the Red River of the North. One natural outlet of the region would seem to be east through the great lakes to the sea, and as geographical conditions are important factors in regulating transportation routes this course must be always a prominent one. There is prospect of a direct route in the future from Manitoba east by the Canadian Pacific, and the Northern Pacific Company is busy extending its road along the south shore of lake Superior, all the roads being eager to grasp the grain traffic of the Northwest. There is also a scheme proposed to open a canal at Duluth, at an estimated cost of about $4,000,000, west from lake Superior, and down the Red Lake river to the Red River of the North. This scheme is claimed to be practicable from an engineering point of view.

PHYSICAL GEOLOGY OF THE DRAINAGE BASIN.

As is characteristic of most of the drainage areas of the Northwest, the country tributary to the Red River of the North possesses none of the bold, picturesque mountain scenery of many of the eastern river valleys. On the contrary, the Red River valley in Dakota and Minnesota has been the subject of remark by all explorers along its course because of its extremely level prairie surface in all directions.

CHANGE IN DRAINAGE.—This stream and the country which it drains possesses especial interest from a physiographical standpoint. There is every indication that in comparatively recent geological times the waters of that region found an outlet by the valley now occupied by the Minnesota river, and, instead of entering Hudson bay, formed a part of the Mississippi system, emptying into the Gulf of Mexico, whose northern coast-line was then well up toward the present mouth of the Ohio river. General G. K. Warren's report, made in 1868 to the chief of engineers of the United States army, contains a map illustrating the then probable condition of the drainage system. For a full understanding of the Red River of the North, past and present, and its drainage basin, a brief description of the causes which led to the present condition of northwestern Minnesota and vicinity may be allowed.

GLACIAL ACTION.—After the epochs in which were deposited the sandstones, limestones, shales etc., and in the latter part of which there was a tropical climate in the north, according to the glacial theory, in what is called the early post-Pliocene period, the climate lowered to Arctic coldness, and a vast ice sheet covered the northern part of North America, gradually extending its front well down toward the present Ohio River region. As the ice accumulated thousands of feet thick in the colder region north its weight pressed the lower portion like a semi-fluid mass toward the south. This ground the soil and rock left by the preceding ages, carrying the material on its surface or in its mass in the slow movement southward, smoothing off the irregularities of the surface, and, in retreating, distributing the "drift", as the eroded material is called, in a generally uniform surface. Then it is thought that over the Northwest, at least, the ice-sheet receded, owing to a change in climate, and afterward

advanced once more, rearranging the upper portion of the drift previously deposited, and, when the cold of the glacier age was finally conquered, leaving northwestern Minnesota much as we find it now so far as contour is concerned, although the rivers have since modified it to a slight extent. It is probable that during the recession of the second glacial sheet, if the term may be used, occurred the change whereby the drainage of the Red River region was diverted from the south to the north.

INDICATIONS OF THE CHANGE IN DRAINAGE.—It may be asked: What are the reasons for assuming that the Mississippi once received these waters? The prominent ones are these: The second glacier had in Minnesota its southern front from about the latitude of Saint Paul, west and northwest, through about the center of the western boundary of the state, and melted as fast as it was pushed down from the north. This must necessarily have given rise to enormous volumes of water, for after equilibrium had been established all the precipitation on the vast region north would have been melted along a narrow belt at the terminus of the glacier-cap. It would be surprising if these great floods had passed off without leaving some traces on the easily eroded drift deposited by the preceding ice-sheet. Nor are remarkable indications wanting of just such action on the largest scale. South of where the Red River of the North takes its final course northward are two long, narrow, and shallow lakes—lake Traverse (pronounced lake Travarre), and southeast of it about 5 miles Big Stone lake. The first flows into the Red River of the North, and the second is drained by the Minnesota river, and the water-shed between them is estimated by General G. K. Warren, with a possible error of 25 feet, as 995 feet above the sea, with an elevation of only 5 or 6 feet above lake Traverse. In very high floods on the Red River of the North a stream of water actually runs from lake Traverse to Big Stone lake. From Big Stone lake the Minnesota river runs southeast, and then northwest into the Mississippi river. In ascending the Minnesota from its mouth it is noticed that the course of the river is in a valley 1 to 4 miles wide, and varying in depth from 100 to 200 feet, or slightly more. There is a regular trough, cut out of the heavy bed of unmodified drift, or till, as it is called, and as the upper portion of the river is neared, and the stream grows smaller, one is more and more impressed with the fact that the present river could never have cut this vast channel. The dimensions of this trough continue the same, the present river meandering through the bottom, while at several places the till has been worn down to the old formation of rock which there underlies it, the solid granite rising out of the alluvium of the bottoms in domes and water-rounded masses many feet in height. Thus it is below the mouth of the Yellow Medicine, and at Granite Falls a great ridge of the metamorphic rock has been worn and broken through. Reaching Big Stone lake, we find still the same trough-like depression in the rather level prairie; in fact, both it and lake Traverse, with the intervening water-shed, lie in the continuation of this same valley; and at the upper part of lake Traverse the bluffs on either side fade away into the wider expanse of the Red River valley. Looking at the little stream, scarcely 20 feet wide, as it flows sluggishly from the end of Big Stone lake, it is apparent that in its present volume it could never have eroded this immense channel; indeed, it has hardly had any effect on the alluvial floor of the valley through which it flows.

It is evident that this Minnesota valley must have been carved out by some vast river; and it is equally as certain that, granting the glacial theory of Agassiz to be correct, which receives by far more credence than the iceberg theory alone, there must have been in this very locality in the post-Pliocene times immense volumes of water produced by the melting ice. Putting these two facts side by side, we are brought irresistibly to the conclusion that the region now drained by the Red River of the North once poured its vastly greater flood through the Mississippi basin into our southern seas. This fact was first pointed out by General G. K. Warren, United States corps of engineers, in his report of 1868.

CAUSE OF THE CHANGE IN DRAINAGE.—The Red River valley proper is a level plain from 10 to 20 miles wide on each side of the river, and is bounded by successive terraces and low hills, rising at the crest of the water-shed to several hundred feet above the river. This level prairie extends north to Lake Winnipeg, gradually widening out, and the slope of the ground is very uniform, about one foot per mile. The superficial deposit of the Red River valley and the traces of old beaches along the terraces point to the former existence of a lake, filling the whole Red River valley, and extending up the Assiniboine valley and over a large territory in Manitoba, 100 to 200 miles wide from lake Winnipeg west in Manitoba, 300 feet deep there and 200 feet deep at the national boundary. There are two theories as to the cause of this ancient body of water and of the change in the direction of the drainage.

GENERAL WARREN'S THEORY.—General Warren thinks that originally the summit at lake Traverse was lower than the land between lake Winnipeg and Hudson bay, which would cause a large lake, with the dimensions just given, and a southern outlet; that an elevation of the surface occurred at the south end of the lake, with perhaps a sinking of the land north; that at all events the south end was elevated enough to raise the water over the divide at the north, and soon the present channel to Hudson bay was cut out, drawing the old lake down below the level of the southern outlet, and finally draining it. Nelson river, before reaching Hudson bay, runs over very rough rapids and falls, the slightly worn rocks indicating a comparatively recent origin of the river.

PROFESSOR WINCHELL'S THEORY.—Another theory is given by Professor N. H. Winchell, state geologist of Minnesota. It is this: The vast quantities of water consequent on the melting of the ice-sheet were hemmed in on the north by the wall of ice and found a way of escape to the south, as already described. As the ice wall receded a lake was formed in the present Red River valley with a southern outlet, this lake gradually growing larger. Finally a time was reached when the ice had melted sufficiently far to allow the water to find a passage by way of

the north, as at present, and when the water level was drawn down the southern outflow was stopped and the lake drained. This ancient lake, believed to be of glacial origin, has been named by Professor Winchell lake Agassiz.

GEOLOGICAL STRUCTURE.—It is a fact that nowhere along the course of the Red River of the North is rock found "in place" until in the vicinity of lake Winnipeg, where the river strikes a light, buff-colored limestone. From its source to near its mouth the bed is in the drift left all over the surface of the rock in that region, and the only rocks met are the erratic bowlders, called "hard heads", scattered through it. The glacier appears to have had its southern and southwestern terminus here, for western Dakota is a driftless region. Taking a cross-section of the valley in a line running east and west, the condition is found to be as follows (see Professor Winchell's article in the *Popular Science Monthly* for June and July, 1873). The divisions can hardly be called strata, although there is a general plan of superposition:

1. Alluvium of the modern river, increasing in thickness toward the north and rather sandy in its nature above the Red Lake river. It is largely restricted to the immediate river bottoms.

2. A finely-divided, loamy-colored clay, without stones, and evidently the deposit from the muddy waters of lake Agassiz. It is thickest at the north, and finally fades away, being unknown about lake Traverse, and hardly found south of Breckinridge. The deposit is of varying width, but is greatest at the north, and south of the national boundary is generally from 15 to 20 miles wide on each side of the river. It formerly covered most of the bed of lake Agassiz, but the changes in that lake disturbed it largely, and east of Moorhead it thins out rapidly, but is much thicker on the west side. The lacustrine deposit is a very peculiar feature of the region. This is the subsoil which has given fame to the Red River valley within late years as a wheat-producing country; and, although hardly superior in that respect to the coarser drift which outcrops east and west, it is making the valley renowned for its almost unparalleled productiveness. As a storehouse to supply the black loam above with the necessary salts it gives a wheat-growing soil claimed to be the equal of the celebrated Tchornoi Zem, or black-earth region of Russia and Hungary. It is also maintained by some that, owing to the cold winters, the frost will bring to the loam from the subsoil renewed vitality each year, making the ground inexhaustible.

3. A sand and gravel strata, caused by the lake waters dissolving the drift, which made its bed, and floating off the clay from the gravel and sand. This is only found under the lacustrine clay.

4. True unmodified drift or till, a blue hard-pan. This drift is spread in a bed of from 100 to 200 feet thick over a large part of northwestern Minnesota, and consists of an uncertain mixture of clay, sand, gravel, and bowlders, all the preceding layers being modifications of it. Of the stone found in it in the Red River region 75 per cent. belong to the Winnipeg limestone, and there are many granite bowlders. This limestone formed the bed and shores of lake Agassiz. Coming to the surface along the edges of the valley proper, 10 to 15 miles east and west of the river, it forms large, slightly undulating plains. South of Breckinridge the lacustrine clay, as already mentioned, thins out, and this drift comes to the surface. East and west it is then more irregular in surface, and is largely modified by action subsequent to its first deposition, forming the hilly, rolling regions about the water-sheds of the basin, the medial moraines about the headwaters of the river on the east, and in Dakota the Coteau des Prairies. As it emerges in the moraines just mentioned the nature is coarser, there being more sand and gravel and large quantities of bowlders. Some of the hills on the east are thickly covered with the rounded and glacier-worn "hard-heads".

5. A layer of bowlders and gravel, with some clay, and occasionally sand and gravel. There is in this considerable slate and lignite from the Cretaceous, which was broken up by the glacier. This layer is probably underlaid everywhere, except in inconsiderable areas, by the Cretaceous deposits, so far as Minnesota is concerned; but in Manitoba the Silurian rocks rise through the Cretaceous, and in places even through the drift appearing at the surface.

Of course there are variations from the above section. In places are found local layers of sand or gravel; then again beds of pure blue clay, etc. Where glacier streams have run down into lake Agassiz, carrying their mud and *debris*, they have formed deltas, now apparent as local modifications, and the modern streams have also had their effects, though the old beaches of lake Agassiz are yet traceable. There is a synclinal dip of the different layers toward the river, and this gives rise to artesian wells in the valley proper. Layers 3 and 5, but especially 5, and, when overlaid by the impervious blue clay, layer 4, give fine wells, the water entering the water-bearing layers in the rolling land. A well about 20 miles north of Crookston is said to throw a stream 5 inches in diameter 40 feet high.

The following section was given by Judge Ives, of Crookston, and probably represents the conditions in that valley:

1. Soil 16 to 30 inches thick, black loam, containing 8 to 13 per cent. of organic matter, and 3.8 to 5.2 per cent. of alkaline salts.

2. Marly clay subsoil, 6 to 10 feet deep, containing 40 to 55 per cent. of carbonate, sulphate, and phosphate of lime, and 5 to 8 per cent. of salts, consisting of sulphides, chlorides, and nitrates of potassa, soda, and magnesia. The balance is silicate of alumina.

3. Layer of sand and gravel from 3 inches to 10 feet thick, holding water.

4. Bowlder clay 40 to 120 feet thick, containing Cretaceous fossils, and in some places a stratum of sand and gravel. Where this sand stratum has not been met in the boring of wells the bed is from 100 to 120 feet deep.

5. A layer of brecciated sand and gravel.

6. Silurian sandstone in place, impervious to water.

Numbers 3 and 5, and the sand and gravel layer where present in number 4, are water-bearing, as mentioned in the geological section of the valley given previously. The great difficulty is to procure good water for domestic use, the surface water being strongly impregnated with alkaline salts. The waters flowing over the fresh-water deposit of the old lake are less highly charged than those whose beds are in the bowlder clay, the unmodified drift, which is largely derived from the marine deposit of the Cretaceous sea. Thus the tributaries further north are less alkaline than those nearer the headwaters of the river. The Bois de Sioux, which flows over the river bottom entirely, is purer than the Otter Tail, which runs through the rolling drift region. The farmers in the valley dig through the loam and marly clay to the water-bearing layer, number 3; if they strike a thin portion of the layer the supply of water is small, but if a thick layer is met it is abundant. It is not permissible to let the water be long in contact with the marly clay in which the well is dug, as it soon becomes saturated with alkaline salts; and accordingly the wells are cased, and this has been done with pine boards usually. It is noticed that the water of wells so cased becomes extremely offensive from the decay of organic matter, and are at times utterly unfit for use. The subject was investigated under the direction of Professor N. H. Winchell, and it was decided that there was no organic *débris* in the soil to produce this effect, but the pine casing used for the well as it decomposed was really the cause of the trouble. It is felt that this habit of casing the wells with wood liable to decomposition may be largely instrumental in producing the disease known as Red River fever. The water of wells dug in the prairie without casing may be charged with organic impurities in summer from the decay of the rank vegetation falling into it, and this is true of the smaller streams which are choked up with grass and weeds. All the surface water and small wells through this region are too strongly mineral to be really good in quality for domestic purposes, but there is a great resource left in the excellent facilities for artesian wells. The lower stratum of sand and gravel, underlaid by the solid rock and capped by the impervious layer of bowlder clay, forms a reservoir all under the valley fed by the rains on the higher lands east and west. Then the sand and gravel stratum in the clay above, where occurring, is liable to contain water. Wells bored into the bowlder clay sometimes strike water, but it is advisable to continue to the lower stratum below the clay, where there is almost a surety of good results.

In the valley proper, as already mentioned, this water-bearing stratum is about 120 feet below the surface, but east and west, on the terraces the depth is of course greater. In the early part of 1881 there had been three wells bored in Polk county—one on the south side of Red Lake river, near Crookston, 190 feet deep, and two 20 miles farther south, 145 feet deep, all throwing copious streams of fine soft water from 25 to 40 feet high. One at least of those south of Crookston gives a stream 5 inches in diameter and 40 feet high.

GENERAL DESCRIPTION OF THE BASIN.

The discussion just completed of the geology of the district will enable a more ready understanding of the topography, hydrography, and other physical characteristics of this drainage basin. It would be difficult to find a river owing its surrounding features more completely to the geological period immediately preceding the present one. The very drainage area is to a certain degree limited in extent by the moraines shoved in front of the advancing ice-sheets already mentioned, and in nearly all places of which information can be obtained for this report the summit line of the basin is determined by a glacial moraine.

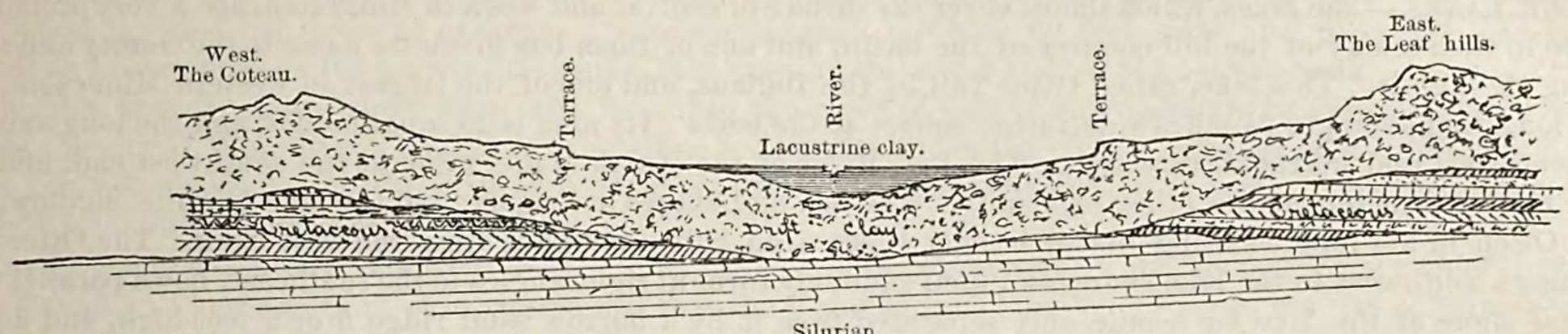
LIMITS OF THE BASIN.—From the geological reports it can be gathered that a rough, hilly section running southwest from the eastern side of Red lake forms the dividing line between the White Earth lake, which empties into a tributary of the Red River of the North, and lake Itasca, at the headwaters of the Mississippi. This continues south a few miles to the east of Otter Tail river, where it is called Leaf hills, and is described as a medial moraine. Then turning southwest, so as to include West Battle lake and lake Clitherall in the basin, the Leaf hills, there considered a terminal moraine, merge into irregular belts of hilly land, which determine the dividing line between the basin and the Pomme de Terre river, which flows into the Minnesota. From there down to lake Traverse the water-shed seems to coincide very closely with the shore line of lake Agassiz as given in the state geological report, and, passing west, it makes the dividing ridge between lake Traverse and the Big Stone river. West of lake Traverse the basin is bounded by the Coteau des Prairies, from which the boundary crosses over to Coteau des Missouri, and so sweeps away up the North Saskatchewan river, 350 miles west of Winnipeg. This is the terminal moraine of the great ice-sheet on the west and southwest, and completes the boundary-line of the Red River basin.

CROSS-SECTION OF THE BASIN.—The best idea of the contour of the basin is to be obtained from the accompanying cross-section through Moorhead, copied from the state geological report of Minnesota for the year 1877. It is only claimed to be largely an ideal sketch.

It will be seen that east and west of the river extends a nearly level plain, the lacustrine clay bed, with a width of 10 or 15 miles on each side of the river along the upper portion, widening further north, and a very uniform slope of 1 foot per mile toward the north, sloping toward the river from both sides slightly; and at Breckinridge about 2½

feet per mile, with not a knoll, not a solitary bowlder, upon its surface to break the monotony of this prairie plain, only the trees, confined to the alluvium along the river, appearing above the prairie grass, excepting the rapidly increasing number of farmers' houses.

This is the wonderful Red River Valley wheat region. At the national boundary it is about 800 feet above the sea-level, and at Breckinridge about 960 feet above the sea. Succeeding the plain on each side is a terrace, probably



SECTIONS ACROSS THE VALLEY OF THE RED RIVER OF THE NORTH AT MOORHEAD (Geological Report of Minnesota, 1877).

the shore line in front of lake Agassiz, rising on the east in a few miles 200 or 300 feet, and beyond this is an undulating surface leading to the hilly moraines which form the dividing ridges. This undulating and hilly portion is prairie country, with groves scattered in places among the knolls, and is fine farming land. From White Earth lake, lying west of Itasca lake, down to the river, the profile is this: The land around the lake is about 1,600 feet above the sea. In the first 4 miles west from White Earth agency the land descends 300 feet to an extensive undulating plain. This plain runs west 25 miles, falling 100 feet; then there is a descent of 300 feet in a few miles to the lacustrine plain adjoining the river. The undulating country on the east is made up of the moraines. Beside the Leaf hills, mentioned as forming the boundary of the basin on the east, is a prominent medial moraine running through the Detroit Lake region, and forming the eastern boundary of the Pelican River basin, a tributary of the Red River of the North. About Detroit the hills are 50 to 100 feet high, and south the moraine is 6 to 7 miles wide, and along the Pelican river the hills are 100 to 150 feet above the water. From Fergus Falls the moraine sweeps southeast and merges into the Leaf hills. In the 25 miles from lake Lida north to Fergus Falls the general surface falls about 100 feet.

ELEVATIONS.—The following are some of the elevations above the sea, obtained mostly from the geological reports. There is a possible error of 25 or 50 feet in them:

	Feet.
Crookston	859
Hill-tops about Detroit	1,500 to 1,600
Perham, Northern Pacific railroad	1,375
New York mills, Northern Pacific railroad	1,418
Otter Tail river at crossing of Northern Pacific railroad	1,327
Pelican river at crossing of Northern Pacific railroad	1,346
Otter Tail and Rush lakes	1,325
East and West Leaf lakes	1,340
Red River of the North at Fergus Falls	1,181
Bridge at Dayton, below Fergus Falls	1,071
Water-shed between lakes Traverse and Big Stone	995
Saint Olaff, on the Saint Paul, Minneapolis and Manitoba railroad	1,344
Lake Clitherall, about	1,341
East and West Battle lakes	1,338
Nidaros plain, southeast of lake Clitherall	1,455
Average elevation of southeast Otter Tail country	1,378 to 1,400
Leaf hills about Eagle lake	1,400 to 1,500
Lund and Millerville townships, in Douglas county	1,500 to 1,600
Leaf Mountain township	1,550 to 1,650
Northwest Effington	1,600 to 1,700
Highest summit of Leaf hills, probably in section 32, township 132, range 38, about	1,750
Thence 7 miles northeast	1,600 to 1,650
About Leaf river crossing	1,425
Thence 6 miles north to second crossing of Leaf river	1,450 to 1,640

No elevations were obtainable of the region in Dakota, and, in fact, a large part of the water-shed in that region has been little surveyed, the land-office maps representing the territory about the headwaters of the Sheyenne and Moose rivers almost in blank.

TWO-FOLD HYDROGRAPHICAL DIVISION OF THE BASIN.

It is evident from the above remarks that the Red River basin can be considered as consisting of two divisions: The plain, constituting the Red River valley proper, and what may be called the hill country, from which most of the tributaries run. Though both are prairie land, they still have very different appearances; one, a level sea of

grass, except where the streams run; the other, at least on the east, consisting of rolling and even hilly prairie, interspersed with an astonishing number of lakes, and in some localities with groves of trees. This division will also serve as a geographical division of the water-power of the basin. All the water-power, with scarcely an exception, is in the hill country, and omitting a possible power at Goose rapids all the available water-power of the river proper is from Dayton, east of Breckinridge, up to the headwaters.

THE LAKES.—The lakes, which almost cover the surface of central and western Minnesota, are a very prominent feature in the scenery of the hill country of the basin, and one of them has given its name to the county and river flowing through it. This lake, called Otter Tail by the Indians, and one of the largest in western Minnesota, is 8 miles long, and averages 2½ miles wide, rather square at the ends. Its area is 20 square miles, and the long axis lies in a southwest and northeast direction. The Red River of the North is the outlet at the southwest end, and the Otter Tail river enters at the other extremity. The bed and shores are sandy, and the lake is quite shallow, Dr. D. D. Owen in his report stating that it is only 4 feet deep half a mile out from the west bank. The Otter Tail river flows southwest to the lake shore, and then suddenly turns at right angles to the southeast, flows parallel with the end shore of the lake for a mile, only separated from it by a narrow sand ridge 5 or 6 feet high, and finally enters the lake. This ridge has the form of an otter's tail; hence the name of the river. It is evident that two forces have been struggling for the mastery: the lake, under the action of the southwest wind, churning up the sand of the lake shore, perhaps brought down by the river itself, and the river endeavoring to break through this barrier. Under their combined action a bar has been formed, and finally a sand ridge, the river running along back of it and the mouth moving southeast down the shore with the growth of the bar, until now it is at the southeast corner of the lake. The lakes, being as they are in the water-power region, exert a very important effect upon the value of the streams, and are merely the filling by water of the innumerable basins and closed valleys left in the drift by the recession of the ice, as will be described in another place. The total number of lakes in the Red River basin in Minnesota, as given on a large and detailed state map, is 700, varying from about 250 square miles in extent (Red lake) to the veriest pool (see map of river). Of these, 241 are counted in the water-shed tributary to the river above Fergus Falls. Many have no apparent outlet, but there is a probability of their filtering through the sandy shores, where such occur, into neighboring lakes or streams. In some of them the evaporation probably equals the supply. Many of these lakes afford fine fishing and hunting, and at the proper season ducks and wild geese abound.

TIMBER.—The timber is mainly confined to the river courses, but in the hill country there are scattered groves. In the valley proper the timber is along the main stream and tributaries entirely, and it is there confined to the river alluvium. On leaving the rolling land, for twenty miles, down to Breckinridge, there is no timber. The geological report states that in the first 10 miles below Breckinridge the river is fringed with groves of burr oak, ash, box-elder, elm, and basswood. Poplar and willow are also seen. Going north from McCauleyville the timber becomes larger, and is found in greater quantities. Between Frog Point and Grand Forks the timber, oak, ash, and elm runs east 2 miles, while on the west it is included within a tangent along the bends of the river. From Grand Forks north for 9 miles the timber belt is narrow on each side, and in the next 9 miles it is 2 miles wide on the Dakota side and three-fourths of a mile wide on the Minnesota side. The same kind of timber occurs as is found up stream. From there down to Big Salt river the timber belt is about 1 mile wide on each side, but fire has injured it on the east; but below this the timber becomes poorer in quality, and is very inferior nearer the national boundary. The matter of fuel supply is a troublesome one to the inhabitants, and in severe winters there has been much suffering in places away from the railroad.

THE RIVER FROM THE NORTH TO WHERE IT ENTERS THE HILL COUNTRY EAST OF BRECKINRIDGE.

At the end of the report on this river are tables giving the lengths and drainage areas of the tributaries, the rainfall, etc.

The interests of navigation have caused several surveys along the river from Breckinridge to the national boundary, and much of the description of that portion of the stream is obtained from the United States engineers' reports. The distance in a straight line from where the river crosses the national boundary to Breckinridge, as measured on a United States land-office map, is 188 miles; and although it does not depart over 6 miles from this line on the west and 3 miles on the east, yet the course is so winding—in some places 1 mile by river accomplishing only 300 feet of northing—that the total distance by river from the south line of Manitoba to Breckinridge is 394 miles, 18 miles more than twice the bee-line distance.

Assuming the river in low stage at Breckinridge to be 957 feet above the sea, and at the national boundary 792 feet above sea-level, the intervening fall would equal 165 feet, making the average slope per mile 0.418 feet. The heaviest slope is probably in a part of Goose rapids, at the mouth of Goose river, where the river falls 4.563 feet in 2.84 miles, equal to 1.6 feet per mile.

SYSTEM OF IMPROVEMENT.—The river channel is cut in the clay of the valley and into the old drift-bed below; hence a portion of the bed is clay, and in places gravel and bowlders are met. The pools are deep enough for navigation,

and the chief problem in improvement for navigation is the removal of snags and the deepening of the channel over clay bars. A peculiarity of the stream is that in the bends the deepest water is nearest the convex bank. This is owing to a clay bar running out from the concave bank. The bar is derived from the bank by cracks forming, into which the rains soak, loosening the clay and sliding off masses into the water. Below Moorhead the banks slope up from this cause within 200 feet from the river to the full height of the surrounding prairie, 40 feet above. The system pursued has been to excavate a channel through the bars 60 feet wide and place the excavated material as a wing-dam on the bars in the bends, thus turning the water toward the convex bank.

For the first 20 miles south from lake Winnipeg the river is said to run through swamps. Twelve miles north of the city of Winnipeg is Andrew's rapids, the first locality where the river strikes the rock in place, which is a light, buff-colored sandstone, the same as is found scattered through the drift farther north. This rock is quarried and used for building purposes in Winnipeg.

From a finely-executed tracing and levels kindly presented for this report by Mr. Thomas Rosser, chief engineer of the Canadian Pacific railway, it is ascertained that the distance from lake Winnipeg to the city of Winnipeg by river is 48 miles and the intervening fall 12 feet, while from the city of Winnipeg to the national boundary the distance by river is 106 miles and the intervening fall 23 feet.

From the national boundary up the worst obstructions to navigation are Goose rapids, at the mouth of Goose river, Turtle River bars, 9 miles above Turtle river, and Pelican bars, 28 miles south of the national boundary. The last two consist of successions of pools and riffles over stiff clay bars, which the river is unable to wash away. The first is described further on. The natural depth of the channel in low water varies from 10 feet in places to 2½ feet or even less.

WIDTH OF THE RIVER.—This varies from 225 to 300 feet below Grand Forks, and above that immediately diminishes from 230 feet to 137 feet, owing to the entrance of the Red Lake river, the largest tributary. Between Grand Forks and Moorhead the width varies from 100 to 200 feet, but above there for many miles the width is about 95 feet and the depth 6 to 10 feet, and near Breckinridge the river widens to 125 feet.

SLOPE OF THE RIVER.—The slope is greatest in the upper portion, averaging 0.74 foot per mile. Between Grand Forks and Frog Point it is 0.365 foot per mile, then further north 0.293 foot per mile, and near the national boundary 0.194 foot per mile. Below the national boundary the slope is about 0.23 foot per mile.

BED OF THE RIVER.—The bed is clay through a large portion of the course, but in places there are gravel and bowlders, as at Goose rapids and between Grand Forks and Frog Point. A few miles below Breckinridge the gravel and bowlders are again met. The banks are about 10 feet high at Breckinridge, and from there down gradually increase to 40 feet or more below Moorhead.

FLOODS AND THEIR CAUSE.—One feature, unknown in the hill country, is the tremendous floods which sometimes inundate nearly the whole width of the immediate river valley, so that steamboats have been known to ride out over the wheat-fields. The extreme range at Breckinridge is 16 feet, and at Moorhead 28 feet, but below Moorhead the rise is as great as 40 feet. The ice melts on the southern part of the basin before it does further north, and the river, swollen by the melting snows, carries it down to gorge upon the yet solid portion. The result is very similar to the state of affairs when lake Agassiz filled the valley. According to the second theory mentioned, the water backs up over the plain, and in high floods even rises over the water-shed beyond lake Traverse, and pursues the course taken by the old lake, which it strives to imitate. This, of course, does not occur every season. In 1880 the river was clear of ice on April 14, and in 1879 was open and free for 208 days.

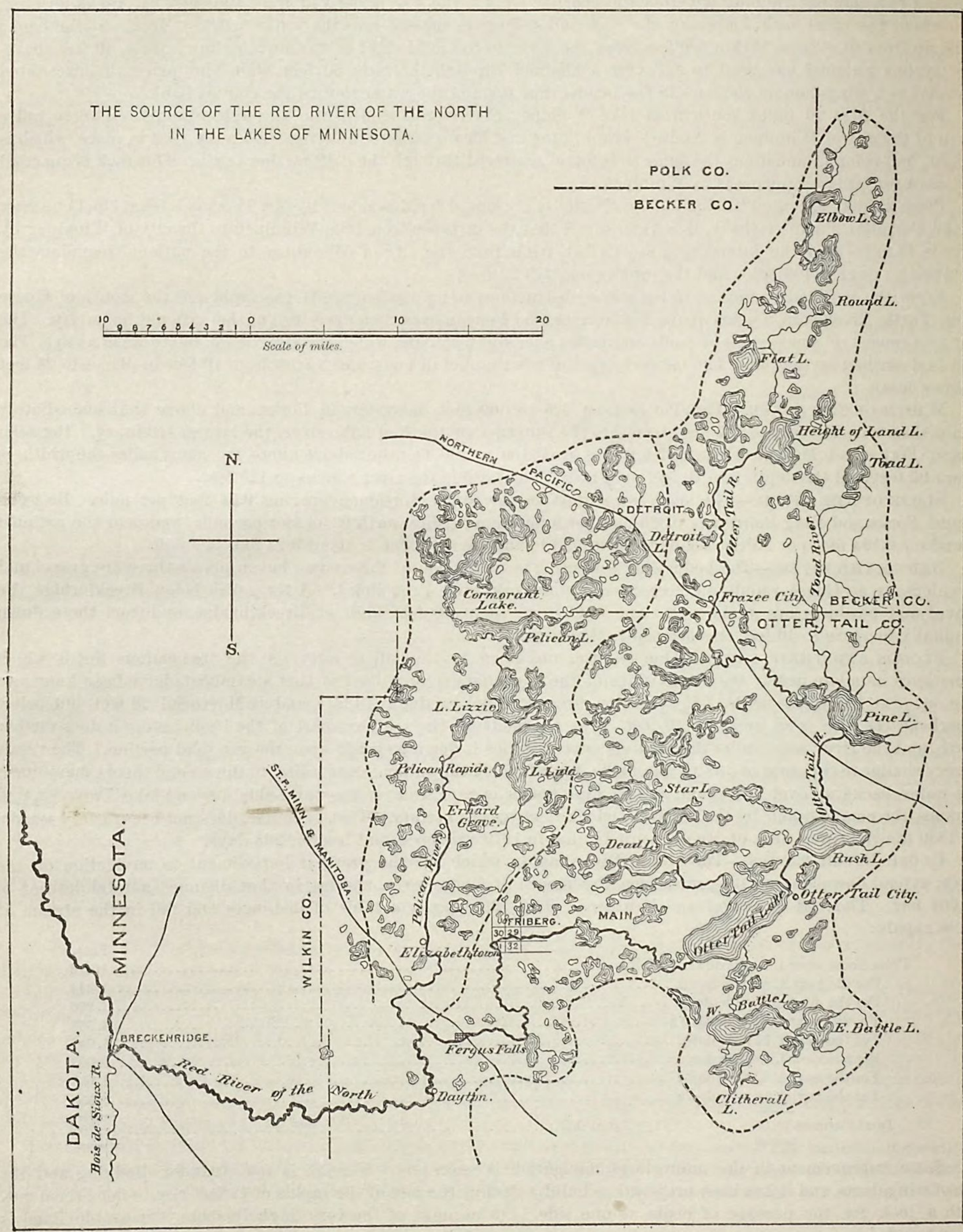
GOOSE RIVER RAPIDS.—The Goose River rapids, which are the greatest impediment to navigation on the river, extend down stream 13½ miles from the mouth of Goose river, making in that distance a total descent of 12.666 feet. The bed is gravel and bowlders. The following is a table of distances and fall in the stream at these rapids:

	Feet.
From Goose river 1.0 mile down the fall is	1.422
For the next 1.82 mile down	1.444
For the next 1.94 mile down	1.226
For the next 2.84 miles down	4.563
For the next 1.74 mile down	1.246
For the next 1.06 mile down	0.660
For the next 1.82 mile down	1.555
For the next 1.14 mile down	0.550
Total distance 13.36 — Total fall	12.666

Some improvement in the interests of navigation is necessary. The fall is too great for dredging and the use of wing-dams, and it has been proposed to build a dam at the foot of the rapids of 12 feet rise to flood them out, with a lock for the passage of boats at one side. On account of the very high freshets a movable dam is recommended.

WATER-POWER OF GOOSE RIVER RAPIDS.—There has been talk in the past of utilizing the rapids for water-power, but nothing has been done in that direction. As the government is about to improve them, it will be perhaps

feasible to make use of the dam for water-power, and if the arrangements are such that this could be done without interfering in any way with the government interests it is probable that terms could be made for its utilization.



Taking the low-water discharge there at 1,100 cubic feet per second, the total theoretical power under 12 feet head is 1,498 horse-power, the available power, at 75 per cent., 1,123 horse-power, and the average flow 1,500 cubic

feet per second. A very serious disadvantage is the great floods previously mentioned. The valley proper of the river there averages one mile wide. The banks of this valley slope back for 200 or 300 feet to the level of the prairie, 40 feet above, and the floods fill this trough sometimes to the brim. It is the opinion of Mr. C. J. A. Morris, engineer of the Saint Anthony Falls Water-Power Company, who has kindly furnished information on the subject, that the only feasible method of using the power would be by wire-rope transmission to mills situated on the bluffs above, out of reach of the floods. He does not think that the power will ever be improved unless a dam is built by the government.

At Breckinridge the river course turns, the stream flowing from the east.

Bois de Sioux river.—The Bois de Sioux, the outlet of lake Traverse, enters here, and is the continuation in a southerly direction of the main river, but it is a small, sluggish stream, only a few feet wide, and furnishes only 5 per cent. of the flow below the junction. This is estimated at 1,000 cubic feet per second in low water; hence the flow of the Bois de Sioux is 50 cubic feet per second in low water, while that of the main stream above is 950 cubic feet. From Breckinridge, in passing east up the stream, the course is through the same level prairie for about 10 miles by land, but the slope of the river is much more rapid, two or more feet per mile. Then the hill country is entered, and the river takes the characteristics of a hill stream, rapids occurring in many places.

DESCRIPTION OF THE RIVER IN THE HILL COUNTRY OR WATER-POWER REGION.

Distribution of the fall.—There is from Otter Tail lake to Breckinridge a total fall of 368 feet, and nearly all of this is in the hilly portion of the river's course, which falls off below Dayton, crossing into the flat plain of the valley proper. This 368 feet fall, then, is practically concentrated in the 34 miles (map measurement) from Otter Tail lake to Dayton, and, as it is still further concentrated in local rapids, there are many fine water-power sites. The banks are usually high enough to hold ponds, and the hard till forming them and the bed make a good foundation for dams.

Uniformity of flow.—One great advantage possessed by this stream from the standpoint of water-power is its extreme steadiness, owing to the large number of lakes, which act as storage reservoirs for it. The river drains above Fergus Falls twenty-five or thirty good-sized lakes, particularly Otter Tail lake; and the Pelican river, which enters 4 miles below Fergus Falls, itself receives the water of ten lakes, each of several miles extent, and three of them 6 or more miles long. The result is that the river scarcely ever varies at Fergus Falls, and below, in the hill country, the variation is rarely more than 2 feet in height from the lowest to the highest stage in ordinary seasons. This is very different from the great backwater floods on the plain below, previously described. Another point which makes these lakes of great value to the water-power, much more than if they occurred in a mild climate, is that while streams fed by swamps and small springs would freeze up solid in winter, as is sometimes the case, this river and many of its tributaries flow steadily on during the cold weather, hardly affected by any freezing of their headwaters.

Flow and power.—The ordinary low-water flow below the mouth of the Pelican river is gauged at 950 cubic feet per second. This gives, at 10 feet head, 1,078 theoretical horse-power. Above the Pelican river the ordinary low-water flow, estimated from the power at Fergus Falls, is 662 cubic feet per second, giving, with 10 feet head, 750 theoretical horse-power. It is probable that the flow of the stream is nearly as much clear up to Otter Tail lake.

From the border of the hill country up to Fergus Falls there is no utilized fall, but the river is rapid, as most of the 224 feet descent of the river from Fergus Falls to Breckinridge occurs in that distance.

Dayton to Fergus Falls.—Although there are slight rapids below Dayton, there is no available power until it is reached, where there is a good power of 16 feet head unimproved. The place is so small as scarcely to be called a village. Above Dayton the river passes through rolling prairie, and many bowlders are met, and sometimes, where the river has worn against a hill, the bank will be 50 feet or more in height. Above Dayton the course of the river is north and south for 4 or 5 miles by land. At the upper end of this stretch the Pelican river, with a low-water flow of 288 cubic feet per second, enters from the north. From there the river's course is east about 4 miles to Fergus Falls, and in that distance, 3 miles below the town, occurs a water-power site, unimproved, where at least 12 feet head can be obtained. The banks are good, and the bed is the stiff bowlder clay common to this portion of the river.

FERGUS FALLS.

This is the location of the greatest water-power of the Red River basin, in the United States at least, and is without doubt the largest available water-power in the country west of the upper Mississippi and east of the Missouri basins. It is the lowest power improved upon the river. The total fall in the stream at the village is 83 feet, and this is so situated that it is possible to use all of it. With the ordinary low-water flow of 662 cubic feet per second, giving, with 10 feet head, 750 theoretical horse-power, the total theoretical power at Fergus Falls, with 83 feet head, is 6,225 horse-power, or, at 75 per cent., 4,669 available horse-power. The descent is so located as to form five falls. Of these the upper three only are utilized. The banks are from 10 to 30 feet high, and are lowest at the upper portion of the descent. They mostly rise sharply from the river to the general level of the country, and

the situation is such that by a system of dams and canals from the different levels the full power could be utilized. The first fall is about three-quarters of a mile from the main portion of the town; the second lies close to the main street, which there runs parallel with the river. Below the third fall the river takes a strong bend to the right.

TABLE OF HEADS AND ORDINARY LOW-WATER POWERS AT THE DIFFERENT LEVELS OF FERGUS FALLS.

Locality.	Head utilized.	Head available.	Theoretical power available with present improvement.	Total theoretical power.	Total effective power (efficiency=75 per cent.)
	Feet.	*Feet.*	*Horse-power.*	*Horse-power.*	*Horse-power.*
First fall	16.0	30	1,200	2,250	1,688
Second fall	12.5	14	938	1,050	788
Third fall	10.0	10	750	750	563
Fourth fall	Not utilized.	About 13	.....	975	731
Fifth fall	Not utilized.	16	.....	1,200	900
Totals	38.5	83	2,888	6,225	4,670

FIRST FALL.—On the upper fall the owners, Messrs. Austin & Newcomb, have 16 feet head, and a new flouring-mill of 150 barrels capacity. They intend eventually to increase the head from 16 to at least 27 feet, making the largest improvement on the river. The plan is to run races down from the dam and locate mills upon them.

SECOND FALL.—At the second fall the power is used by an establishment on the right bank, called the Bee Hive, embracing a saw-mill, carding-mill, planing-mill, and one or two little industries. The head could be raised to 14 feet, but more than that would cause overflow into a small portion of the village.

THIRD FALL.—The lowest utilized power is at the third fall, where, on the right bank of the stream in descending, is a flouring-mill, newly erected, intended to have a capacity of from two to three hundred barrels per day. The head used is 10 feet.

FOURTH AND FIFTH FALLS.—These two falls below are yet in their natural condition. It is evident that the possibilities at Fergus Falls are by no means developed. At the second fall, when seen in the winter, the water was rushing over the crest of the dam in a heavy body while the wheels were running, and at the third fall the one flouring-mill could not begin to exhaust the flow. As stated before, the comprehensive system of races along the banks from the different levels would be mostly feasible, and it appears to be the proper way to fully improve the power. The bed of the river is a hard clay and gravel, with big bowlders of granite and other rock, the till before described, and must be firm, or the rapids would have been long ago worn away.

The nature of dam exclusively used on the stream is a log crib-work. A crib is built sometimes extending 120 feet up stream, setting back each course in a series of steps. The face is planked over, and brush and gravel are filled in on the toe of the dam and up the back.

LOCATION OF THE TOWN.—The town is situated on the Fergus Falls division of the Saint Paul, Minneapolis and Manitoba railroad, and is the most important place in that region of country. Being situated in the midst of the grain country and on the railroad, there is every facility for the manufacture of flour.

THE RIVER ABOVE FERGUS FALLS.

LOCATION OF THE POWER.—The level of Otter Tail lake is 144 feet above the river at Fergus Falls. The greater part of this fall is located in the 15 miles by river (map measurement) below section 29, in southwestern Friberg township. For all this distance there is a good current, with several rapids, some of which could be utilized for power, but as yet nothing has been done. Within 3 miles of the village of Fergus Falls, and above the first fall, is an unutilized power of 13 feet available head, beside the 14 feet unutilized at the first fall. The knolls along the stream rise 30 or 40 feet above the water. In sections 29, 30, and 31 of Friberg township the rapids are heavier, and the stream is a succession of rapids for 2 miles or more. The bed is clay and bowlders, and the banks are not all high. In one place there is a good bank upon one side, but a low meadow on the other. However, there are one or two good sites there; one especially, where there is a fall of 30 feet, probably the most of it available. Above section 29 of Friberg the river is sluggish and widens out into several lakes. There is no fall of any consequence until the stream is ascended up to the southeast part of Main township, in section 35, where there is an unimproved fall of about 12 feet, called Monitor falls. These have a bowlder bed, and are described by Dr. Owen in his report as heavy rapids. One or two miles above the river emerges from Lost lake, which is 2 or 3 miles long. About 1 mile from Lost lake is Otter Tail lake, the source of the Red River of the North.

TRIBUTARIES OF THE RED RIVER OF THE NORTH.

The water-power upon these tributaries is practically in the hill country, as is the case with the main stream. The larger ones, especially on the east side, are usually steady in their flow, because fed by lakes to so great an extent; but the smaller ones, starting below the lake region, partake more of the character of a typical prairie stream swollen high by the melting snows, but dwindling low in summer and in winter freezing up. The only ones that merit particular attention in a water-power report are the Red Lake, Otter Tail, Pelican, and Sheyenne rivers.

OTTER TAIL RIVER.

This is treated first, not because it is the largest, but because above Otter Tail lake it corresponds with the main river. The source is Elbow lake. Thirty-eight miles below (map measurement) are the two Pine lakes. Into Pine lake empties Toad river, about 15 miles long, and the outlet of several small lakes. From the head of Pine lake to Rush lake is 12 miles, and from the head of Rush lake to the head of Otter Tail lake the river runs 6 miles. Otter Tail lake is about 8½ miles long. There is very little water-power upon the Otter Tail river, the only utilized one being at Frazee City, on the Northern Pacific railroad, where the elevation of the river bed is stated in the geological reports to be 1,327 feet, while Otter Tail lake is 1,325 feet above the sea. There are several feet of possible error in these elevations, which probably accounts for the slight difference of 2 feet in elevation; but it goes to show that there is very little fall in the river below Frazee City. Below Frazee City, in Hobart township, the river is extremely crooked, and between Pine and Rush lakes is wide and swampy. About Frazee City it is from 20 to 40 feet wide. There is some slight fall above Frazee City, but the stream is of little consequence so far up.

Utilized power.—At Frazee City are a flouring-mill and a saw-mill under 12 feet head, the flouring-mill using 60 horse-power, and the saw-mill, which only runs in summer, having a capacity of 75 horse-power. Mr. Frazee, the owner of the flouring-mill, states that the total available power of the river at Frazee City, under 12 feet head, is 100 horse-power in ordinary stages of the river, which would require a flow of 97.9 cubic feet per second, considering the efficiency 75 per cent. This estimate is probably slightly less than the actual discharge, as with the methods in vogue the utilized power is, in all probability, less than 75 per cent. of the theoretical power. Mr. Frazee says that the high-water flow is about four times the volume of the low-water discharge, but they have no heavy freshets. There is a small power on Toad river, running a flour-mill of about 40 horse-power size.

PELICAN RIVER.

This river rises in some small lakes just north of Detroit lake and flows south 43 miles (map measurement) into the Red River of the North. From Detroit lake to its mouth the fall is not far from 260 feet. The low-water discharge at the mouth is about 288 cubic feet per second, giving, with 10 feet head, 326 theoretical horse-power. The river in the lower part of its course is from 30 to 40 feet wide, and the flow is increased somewhat, below Detroit lake, by the discharge from lakes on the east. The stream drains at least ten lakes, and, owing to these, is steady in its flow, although it is not quite so reliable as the main river. The variation in height at Detroit during the year is stated to be 18 inches, the highest water being in April, when the snows melt. As on the main stream, the banks and bed consist of clay, gravel, and bowlders. The country about it is quite hilly.

Improved powers.—The first power improved on the upper part of the stream is at Detroit, on the Northern Pacific railroad, just above Detroit lake, where is a flour-mill called the Detroit Lake mills. They have three run of stones under 12 feet head, but in midwinter use steam. Being near the headwaters, the flow becomes small in cold weather. Six miles below this is a good power, unimproved, of 10 feet head. Twenty miles from Detroit is Pelican rapids, where there is a flouring-mill and a saw-mill under 10 feet head, using 40 horse-power each. The owners of the property estimate the total available power of the river there, under 10 feet head, at 200 horse-power. There are two or three unimproved powers at the place. In Erhard's Grove township there is some available power untouched. Below this a stream enters from the east, the outlet of Long and Jewett lakes. The next improved power is at Elizabeth, where there is a four-run flouring-mill, using about 60 horse-power at 15 feet head. The discharge there must be about the same as at the mouth, giving 326 theoretical horse-power with 10 feet head, or 245 available horse-power. According to the proprietors of the mill, the available power at 10 feet head is about 283 horse-power.

RED LAKE RIVER.

This river is by far the largest tributary stream of the basin in the United States, and from a water-power point of view is nearly as important as the main river, for the reason that it lies very largely in the hill country, while the Red River of the North has all its water-power upon the upper waters. The mouth is just below latitude 48° north, and the general course is west from Red lake, which lies in latitude 48°. The source is about 30 miles

southeast from Red lake, in a lake three-quarters by half a mile in extent, within a few miles of the upper waters of the Mississippi. The distance from source to mouth in a straight line is 105 miles; by river it is over 200 miles. The total area of the water-shed is 6,518 square miles.

RED LAKE.—Red lake, which serves a very important office to the water-power of the river in steadying the flow, is the largest lake lying wholly in Minnesota, and, next to lake Superior and the far northern Lake of the Woods, is the largest sheet of water connected with the state. It consists of two parts, one lying northeast of the other, connected by a strait about 2½ miles wide. The area, as estimated from the United States postal map, is a little over 250 square miles. The lake is described as being shallow in proportion to its size, and as having no islands. Many tributaries enter it from various directions, and it is really the feeder and regulator of the Red Lake river, as the stream emptying into the lake which bears that name is a small, crooked brook, hardly more than 15 feet wide, although deep enough to allow of canoe navigation. The river below Red lake is very crooked, one stretch of 33 miles by land including about 100 miles by river. The width in the lower part averages about 150 feet. It is considered navigable up to and above Crookston. Starting from Fisher's landing, about 7 miles from the mouth by land, is an old channel of the river, 25 or 30 miles long, with the mouth about 12 miles below the present mouth of the river. This, called Grand Marais, is now a swamp, on which hay is cut. The largest tributaries are the Clearwater, entering from the south 18 miles by road above Crookston, and, about the same distance above the Clearwater, the Thief river, from the north. Below the two is the Black river, entering from the north, the smallest of the three.

FALL.—In a report on a proposed transportation route to lake Superior the total descent from the Thief river mouth to Crookston is stated to be 230 feet, while above Thief river the stream is deep and sluggish, and it seems probable from the elevation of White Earth lake, given in preceding pages, and from the direction of the streams between it and Red lake, that the total descent from Red lake to the mouth of the river is not less than 400 feet. At all events, there is enough fall to give rise to many available powers. The bed and banks are the drift, as usual in this region, and considerable sand is carried down, it is said, into the Red River of the North. The banks are from 10 to 30 feet high and usually steep, so that ponds would be mostly confined to the course of the stream.

FLOW AND POWER.—Owing to Red lake's forming so excellent a reservoir, the variation in the height of the river is seldom over 4 feet at an ordinary section of the bed and bank; but at rare intervals there is a heavy freshet, due to the rapid melting of the snow. The highest rise known at Crookston was 20 feet. The discharge was carefully estimated by Mr. James D. Skinner, a civil engineer, residing at Saint Paul, who states it at 982.86 cubic feet per second when near the lowest stage, an amount only about 17 cubic feet per second smaller than the flow of the Red River of the North below Breckinridge. This flow would give, with 10 feet head, a theoretical power of 1,115 horse-power.

AVAILABLE POWERS.—There are as yet no utilized powers upon the stream, but there are thirty or more available ones. In the innumerable bends there are frequent opportunities for cutting across a neck and utilizing the intervening fall. The reason for the power of the river lying idle is the unimproved state of the country, with the little demand for water-power. Claims are being taken up, and the land broken, so that Polk county probably has a fine future in store for it.

There is a scheme, already mentioned, for connecting the Red River of the North with lake Superior by means of a canal to Red lake, and so down the Red Lake river. If this is ever accomplished, there will be restriction in the use of the water-power of the stream.

POWER AT CROOKSTON.—The county-seat, Crookston, a town of about 2,000 people, is situated on the Saint Paul, Minneapolis and Manitoba railroad, and also on the river. There is an unimproved power there, and in December, 1880, steps were being taken by the citizens to form an hydraulic stock company to take the matter in hand. The total expense of the improvement was estimated at $40,000. In passing the town the river takes a wide sweep around it. The beginning of this curve is only a short distance from the outskirts of the town, and from that point a depression in the ground, evidently an old river channel, runs for about 3,600 feet across the neck to the river bank below, which it meets a short distance below the railroad crossing.

PLAN OF IMPROVEMENT AT CROOKSTON.—The scheme is to build a dam at the beginning of this old channel and run a hydraulic canal along the side, stationing manufactories at the lower end near the river and using the lower part of the old channel for a tail-race. The plan is a good one. The greatest amount of excavation would be right at the head of the canal, where for a few rods the channel is filled up. The site was surveyed in the fall of 1880 by Mr. Skinner, of Saint Paul, who made the following estimates, as printed in one of the Crookston papers: Discharge of river at low water, 982.86 cubic feet per second; mean velocity of the river, 1,353 feet per second; theoretical power at 12 feet head, 1,336.165 horse-power. To conduct this amount of water through the depression to where it would be used would require a canal with a sectional area of 300 square feet and a slope of 1 in 3,000. The fall of the river from the dam site to the water surface at the proposed tail-race is 4.49 feet. In Mr. Skinner's report it was proposed to build a dam with a head of 8 feet, for which the site is well adapted. The river there is about 150 feet wide, and it bends sharp to the left in its course. The concave bank is some 30 feet high just below,

but at the old channel, which starts from the concave bank at the bend, it is not more than 10 or 15 feet high. The left or convex bank is much lower, sloping off more gradually, but will allow an 8-foot dam. With the 4.49 feet natural fall and an 8-foot head raised by the dam, the total head is 12.49 feet, or, allowing for the fall in the canal, somewhat less than 12 feet. To get 12 feet available head it would probably be necessary to raise the dam at least a foot more. It is proposed to build a pile-dam, at a cost of about $8,000, and a canal 3,600 long. The mills and manufactories would be near the line of railroad to Saint Paul, and could easily be connected by side-tracks.

UNIMPROVED POWER ABOVE CROOKSTON.—About 1 mile above Crookston is a bend in the stream, where there is a power lying idle. This would, of course, be destroyed if the other power below was improved. The facts about it were stated by a gentleman interested to be these: The available head is 12 feet. There is an old channel across a bend, as in the location below, and the plan would be to use this for a tail-race, building mills along a short canal at the side. The river is there 120 feet wide and 3 feet deep. The pond would be 1 mile long, averaging 650 feet wide and 12 feet deep; hence the head of water at the dam would be about 9 feet. The whole improvement was estimated to cost $15,000. When interviewed, the informant was on the train on a journey with the object of getting capitalists interested in the power. Above Crookston are many good powers, which will be valuable when the country becomes more settled.

CLEARWATER RIVER.

The Clearwater is the largest tributary, and has the only utilized power in the basin of Red Lake river. It is not so reliable as the Red Lake river, as it is fed largely by swamps, which freeze in winter, instead of by lakes; but it is nevertheless a very good stream. There are many good powers improved. The only improved one is at Red Lake falls, 1 mile from the mouth. There the water passes in a succession of falls and rapids over a clay, gravel, and bowlder bed. The river falls 26 feet in a distance of 1,350 feet. There are a grist-mill and a saw-mill upon it, using 30 horse-power each, under a head of 7 feet. The dam is a brush dam, 2 feet high and 50 feet long. The power of the river in ordinary stages is considered at Red Lake falls to be at least 200 horse-power under 7 feet head.

SHEYENNE RIVER.

This river rises in Sheridan county, Dakota, about latitude 47° 30′ north, and, flowing in a general southeast direction 308 miles (map measurement), enters the Red River of the North 12 miles by land north of Moorhead, in latitude 47° north. The headwaters are only a few miles removed from the James river (called Jim River), which flows into the Missouri, and for nearly four-fifths of its course it flows almost parallel with that stream in an east and south direction; then, suddenly turning, it runs northeast to the Red River of the North. Valley City, a promising young town on the Northern Pacific railroad, is on the river, 135 miles from the mouth (map measurement). In a straight line it is 55 miles a little south of west of the mouth. The most southern point of the river is 40 miles south of this line. The country about the upper waters has never been surveyed, so far as ascertained, but it is known that the river runs throughout in the prairie region of Dakota. From the mouth to Norman, a distance of some 30 miles (map measurement), the river runs in the level plain of the Red River valley proper; there the course changes, flowing more from the southwest, and above Norman it lies in the region corresponding to the hill country on the east side of the Red River basin, although less undulating. Above Norman there is a more rapid descent than below, and, although the current is moderate, still there is considerable fall in the stream. It is said that 9 or 10 feet fall can be obtained every 5 or 6 miles. Below Norman, where the river flows in the lacustrine plain, the slope is only about 1 foot per mile.

The western tributaries of the Red River of the North are not, as a rule, so steady in their flow as those on the east, and it is very natural that this should be the case, because the greater number of them approach in character the true prairie stream. The Sheyenne is probably one of the most reliable. This river never freezes up in the severe winter so as to make it entirely useless for water-power. This may be due to lake Minne-wa-kan, or Devil's lake, a sheet of fresh water some 30 miles long by 5 broad, which, although it is claimed to have no visible outlet, probably drains into the Sheyenne. Still the water-shed is narrow there, and the discharge of this lake must be rather small. The bed of the stream, in the lower half at least, is in the true drift, the bowlder clay consisting of clay, gravel, and bowlders. The last 30 miles is in the lacustrine deposit described on preceding pages. About Valley City the river winds along through a flat plain of varying width, bordered by bluffs over 50 feet in height. This is probably characteristic of the greater portion of the river. Below Norman the banks are from 12 to 20 feet high. The channel is very winding, causing many places where races could be easily cut across necks of land. The rim banks are usually of good height, and would prevent large overflows from ponds, and the fall of the river appears to be largely concentrated in small distances. There will be a long still water, and then a small riffle over a bowlder bed. Thirty-five miles below Valley City there is good timber along the river, oak, elm, etc. At Valley City there is also timber along the river, and up the bluffs to some extent. It is again heavier below. The land is very fine for wheat. At Valley City the river will average perhaps 50 feet wide, and below Norman, at the

crossing of the Northern Pacific railroad, somewhat less. Although not a very rapid stream, there are many places where, owing to the favorable banks, a small power can be obtained, but very few of them are utilized.

POWER.—About Valley City the millers say that with 9 feet fall they can depend on 25 horse-power for ten months of the year, which, with their methods, will turn three run of stones and the necessary machinery. Sometimes they have 200 horse-power, and occasionally the power runs very low in winter. Considering that they use 75 per cent. of the theoretical power, this would give an ordinary low-water flow of 2,056 cubic feet per minute, or 34.26 cubic feet per second, which seems a very low estimate for a river of that length; but it must not be forgotten that the water-shed is narrow and the rainfall light in that section.

UTILIZED POWER.—There is no utilized power above Valley City. There is a good situation near fort Totten, at lake Minne-wa-kan, just above where the old road crosses, where a 12-foot head is available. The first improved power is at Valley City, where there is a small mill, with 9 feet head, backing the pond up some 6 miles. Six miles below there is a mill, and 6 miles further down another. These have each about 10 feet head. At fort Ransom, a few miles above the southern bend of the river, where 17 feet head is obtainable, there is prospect of a mill being erected. Although the slope is so slight below Norman, the banks are high enough to allow of making ponds and getting a moderate head of water. This has been done just below the Northern Pacific railroad crossing, where there is a dam, but no further improvement.

CONSTRUCTION OF DAM.—The form of dam that appears most suitable for this region is a spar dam, or else brush dam. The timber, brush, gravel, and bowlders are at hand for its construction. The dam at Valley City was thus built: A row of logs was laid on the bed in the direction of the current; a stringer was put across these at the face of the dam, and another course of spars laid on this, the intervening spaces being filled in with "hard heads". This was continued, bolting the stringers to the spars, until the required height was reached, and then the back of the dam was planked. The river banks are high there, giving good clay abutments. A quantity of gravel was thrown in around the ends of the dam, to prevent the crawfish from boring holes in the clay and weakening the abutments. The river is there about 50 feet wide.

The principal tributary of the Sheyenne is the Maple river, entering about 10 miles from the mouth. It is a small stream of no special importance, nearly freezing up in winter, like the upper James river.

TABLES OF TRIBUTARY STREAMS, DRAINAGE AREAS, RAINFALL, ETC., OF THE BASIN OF THE RED RIVER OF THE NORTH.

These tables are necessarily fragmentary in part, as incomplete information was at hand. The records of rainfall and temperatures are obtained from the valuable publications of the Smithsonian Institution at Washington. The lengths of the rivers were estimated from the state maps, published by the United States land-office, except where designated as survey measurements. The drainage areas were also largely obtained from these maps. The rainfall, as given for the basin of each tributary, is an approximation based on the Smithsonian reports and charts.

EXPLANATION OF THE DIFFERENCE BETWEEN THE EASTERN AND WESTERN TRIBUTARIES.—On an examination of the tables a curious fact is apparent: the drainage area tributary on the east of the main stream has over 33 per cent. greater annual precipitation than that in Dakota. This is because the Red River of the North lies near and almost parallel with the western margin line of the effect of the moist winds from the Gulf of Mexico. The western tributaries, notably the Sheyenne, rise in a section having a very small precipitation of about 15 inches per annum, while the larger ones of the eastern tributaries have their headwaters in a section supplied with about 25 inches each year. This, taken in connection with the difference of topography, explains why it is that the tributaries from the west are so much smaller in proportion to the areas drained than those on the east. That portion of the basin in Minnesota is largely covered with lakes, many of which act as storage reservoirs, while in Dakota are few lakes, and the general level is more uniform than that on the east side of the main stream. The consequence is that the evaporation bears a much larger proportion to the precipitation on the west than it does on the east side of the river. Taking into account the less rainfall and the greater percentage of evaporation to the rainfall it is easy to understand the peculiarities shown in the tables.

COMPARISON OF THE UPPER PORTION OF THE RIVER WITH THE BOIS DE SIOUX.—For example, the area tributary to the main stream above Breckinridge is 2,751 square miles. At Breckinridge the Bois de Sioux enters, with a drainage area of 1,996 square miles, increasing the area tributary to the river to 4,747 square miles. The ordinary low-water flow of the main river above Breckinridge is 950 cubic feet per second, while that of the Bois de Sioux is only 50 cubic feet. The basin of the Bois de Sioux is nearly 75 per cent. of that belonging to the main stream above Breckinridge, while its ordinary low-water flow is only 5¼ per cent. of that of the main stream. This is accounted for by the fact that the annual precipitation on the upper waters of the Red River of the North is at least 25 inches, while about the Bois de Sioux it certainly does not average over 20 inches. Also on the basin of the latter the evaporation is nearly the equal of the precipitation in Dakota and in the marshes about lake Traverse. It must not be forgotten that the Bois de Sioux is not so steady in flow as the main river, and hence the difference would not be so great were the average instead of the ordinary low-water discharge taken into consideration.

COMPARISON OF DIFFERENT SECTIONS OF THE RIVER.—Again, the volume of the main stream does not increase in nearly so great a ratio as the drainage area tributary to it. The United States engineers give the *average* discharge below the mouth of the Sheyenne as 2,000 cubic feet per second. Comparing this with the *ordinary low-water* flow at Breckinridge, we find it to be just double that, while the drainage area above the mouth of the Sheyenne is over three times as great as that tributary to the river at Breckinridge. The Sheyenne, although its drainage basin may be assumed from the map to be 8,300 square miles, is really a very inconsiderable addition to the main stream in low water.

The peculiarities stated above are all illustrated in the last column of the table of the Red River of the North. Under ordinary circumstances the ordinary low-water discharge per square mile of drainage area increases as the area increases, while here the reverse is the case, and it is explained by the distribution of the rainfall and of the lakes. It will be noticed that on receiving the discharge of the Pelican river, whose basin abounds in lakes, the discharge per square mile increases and is at that place the largest.

MEAN PRECIPITATION IN RAIN AND MELTED SNOW AND TEMPERATURE AT PLACES IN THE BASIN OF THE RED RIVER OF THE NORTH.

Place.	Spring.	Summer.	Autumn.	Winter.	Year.	Length of observations.	Summer temperature.	Winter temperature.	Length of observations.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*		° ′	° ′	
White Earth agency	.....	.....	.....	.....	24.74	Sept. 1869, to Mar., 1870	71.46	9.21	Sept., 1869, to Mar., 1870.
Douglas county	13.97	13.61	9.96	5.82	43.36	May, 1859, to May, 1861	.....	.....	
Breckinridge	5.41	12.05	3.17	2.45	23.08	Oct., 1872, to June, 1876	.....	.....	
Fort Abercrombie	4.87	8.67	3.46	1.85	18.85	Aug., 1860, to Oct., 1874	70.94	7.95	Feb., 1859, to Dec., 1870.
Fort Ransom	5.14	4.96	3.38	1.82	15.30	Dec., 1868, to Nov., 1871	67.08	10.38	Dec., 1868, to Dec., 1870.
Pembina	4.02	7.24	2.71	1.53	15.50	Aug., 1871, to June, 1876	70.42	14.63	1851, to 1853.
Winnipeg	4.36	9.28	5.00	2.66	21.30	Jan., 1869, to Dec., 1876	64.07	7.66	Jan., 1869, to Dec., 1870.

RED RIVER OF THE NORTH.

Station.	Distance by river to station designated by number.	Intervening slope per mile to station designated by number.	Tributary area above station.	Gauged flow at ordinary low stage, per second.	Ordinary low-water flow per square mile of drainage area, per second.
	Miles.	*Feet.*	*Square miles.*	*Cubic feet.*	*Cubic feet.*
1. Foot of Ottawa lake	.....	.....	1,442	.....	.....
2. Fergus Falls	*26 (1)	.....	1,613	662	0.410
3. Mouth of Pelican river	*4 (2)	.....	2,281	950	0.416
4. Breckinridge	*30 (3)	.....	4,747	1,000	0.217
5. Mouth of upper Wild Rice river	†79 (4)	.....	6,178	.....	.....
6. Moorhead	†18 (5)	.....	6,283	.....	.....
7. Mouth of Sheyenne river	.....	.....	14,612	.....	.....
8. Frog point	†118.5 (6)	.....	19,702	.....	.....
9. Grand Forks	†35 (8)	0.365 (8)	26,870	‡2,000	0.074
10. Mouth of Turtle river	†25 (9)	0.403 (9)	27,721	.....	.....
11. Mouth of Big Salt river	†30.5 (10)	.....	28,648	.....	.....
12. Foot of Pelican bars	†40 (11)	0.293 (10)	31,669	.....	.....
13. National boundary	†48 (12)	0.194 (12)	39,577	‡2,800	0.070
14. City of Winnipeg	106 (13)	0.217 (13)	.....	.....	
15. Lake Winnipeg	48. (14)	0.250 (14)	.....	.....	

* Map measurement. † Survey. ‡ Approximate.

TRIBUTARIES OF THE RED RIVER OF THE NORTH DOWN TO THE NATIONAL BOUNDARY.

Name.	Length along general course.	Drainage area.	Annual precipitation.	Name.	Length along general course.	Drainage area.	Annual precipitation.
	Miles.	*Sq. miles.*	*Inches.*		*Miles.*	*Sq. miles.*	*Inches.*
Otter Tail river and lake	56	1,442	25	Red Lake	135	6,518	22
Pelican river	43	668	25	Turtle river	48	799	15
Bois de Sioux river	27	1,996	20	Big Salt river	50	846	15
Upper Wild Rice river	75	1,215	18	Park river	50	1,271	15
Sheyenne river	308	8,302	15	Swamp river	4	1,013	20
Buffalo river	63	1,003	22	Tamarack river	40	637	20
Lower Wild Rice river	85	1,991	22	Two Rivers	30	991	20
Goose river	50	878	15	Pembina river	130	6,700	15
Sand Hill river	55	644	20				

INDEX TO REPORT ON THE WATER-POWER OF THE NORTHWEST.

A.

Page.

Above Big White Face river, power of Saint Louis river 73
Above Crookston, unimproved power on Red Lake river 91
Above Fergus Falls—
  Location of the power of the Red River of the North 88
  The Red River of the North 88
Accurate calculations of flow of streams, impossibility of 7
Action, glacial—
  In the Fox River valley 18
  On the drainage basin of the Red River of the North 79, 80
Action of woodland on the flow of streams of the Northwest 9
Age, glacial, effect on modern surface features of the Northwest 6
Amount of aqueous precipitation in the Northwest 7
Ancient course of Upper Fox river 54
Ancient hydrography of the Northwest 2
Ancient valley of the Wolf river, geological history of the 18
Annual precipitation, distribution of, in inches, of basin of Red River of the North and western drainage area of lake Michigan (table) 8
Appleton 27–35
  Basin at Middle level at 32
  Dams at Lower level and at Neenah 45
  Dam at Middle level 50, 51
  Dam at Upper level 45
  Fall and power of Lower level at 33
  Fall and power at Middle level at 31
  Fall and power at Upper level at 29
  Freighting facilities of 28
  History of the Middle level at 31
  Hyde and Harriman canal at Lower level at 34, 35
  Long pier at Upper level at 29, 30
  Lower level at 33–35
  Method of building dam at Middle level 51
  Middle level at 30–33
  Navigation channel at 28
  North-shore race at Middle level at 31, 32
  North-shore race at Upper level at 29
  Ship-canal at Upper level at 30
  Stone pier at 45
  Unused power at Upper level at 30
  Upper level at 28–30
  West's canal at Middle level at 32, 33
  West-shore race at Lower level at 34
  Wooden bulkheads of Hyde and Harriman canal at Lower level 52
Aqueous precipitation, amount of, in the Northwest 7
Areas, drainage—
  Lengths, low-water discharges, and power of tributaries of Menominee river (table) 63
  Of lake and river basins of the Northwest (table) 1
  Rainfall, tributary streams, etc., of basin of the Red River of the North, tables of 92, 93
  Basins of the Northwest, system of drainage 1, 2
  Basins of lake Michigan (table) 14
  Lake Michigan, records of precipitation and temperature for (table) 15
  Lake Michigan, distribution of the precipitation on the 15
Artificial reservoirs of the Lower Fox river 22
Available powers—
  Of the Lower Fox River, location of the (table) 21
  Of the Red Lake river 90

B.

Page.

Bad river 78
Bad Water rapids, Menominee river 59
Basin at Middle level at Appleton 32
Basin—
  Lower Fox river 14
  Lower Fox, system of drainage of the 17
  Menominee river 14
  Menominee river, geological character of 57
  Menominee river, main topographical features of 58
  Saint Louis river, rock of lower section of 72
  Saint Louis river, upper and lower sections of 71, 72
  Upper Mississippi 5
Basin, drainage—
  Lower Fox, physical discussion of the 17
  Of Menominee river, dimensions of 57
  Of the Lower Fox river, geological history of the 17–19
  Of the Red River of the North, glacial action on the 79, 80
  Of the Red River of the North, physical geology of the 79
Basin of the Red River of the North 5
  Cause of change in drainage of the 79, 80
  Cross-section of the 82, 83
  Elevations in the (table) 83
  General description of the 82, 83
  General Warren's theory on the change in drainage of the 80
  Geological structure of the 81, 82
  Indications of change in drainage of the 80
  Lakes of the 84
  Limits of the 82
  Mean precipitation in rain and melted snow and temperature at places in (table) 93
  Professor Winchell's theory on the change in drainage of the 80, 81
  Timber in the 84
  Twofold hydrographical division of the 83, 84
Basins—
  Lake and river, of the Northwest, drainage areas of (table) 1
  Western drainage, of lake Michigan, areas of (table) 14
Bed of the Red River of the North 85
Beds, sand and gravel, influence on flow of streams of the Northwest 8
Big Quinnesec falls, Menominee river 60, 61
Big White Face river, power of Saint Louis river above 73
Big White Face to Floodwood river, power of Saint Louis river from 73
Bois Brulé river—
  Flowing into lake Superior 78
  Tributary to the Menominee 63, 64
Bois de Sioux river 87
  Comparison of the upper portion of the Red River of the North with the 92
Boundaries, state, distribution of lakes of the Northwest according to (table) 9
Boundary, national, tributaries of the Red River of the North down to the (table) 93
Breckinridge, entrance of Red River of the North to the hill country east of 84–87
Building dam at Middle level, Appleton, method of 51
Bulkheads, wooden, of Hyde and Harriman canal at Lower level, Appleton 52

C.

Page.

Calculations of flow of streams, impossibility of accurate 7
Canal Company, Green Bay and Mississippi 20
Canal, Hyde and Harriman—
At Lower level at Appleton 34, 35
At Lower level, Appleton, wooden bulkheads of 52
Canal, proposed, to connect lake Superior with the Red River of the North 71
Canal, ship—
At Grand Kaukauna 39
At Upper level at Appleton 30
Canal, West's, at Middle level at Appleton 32, 33
Capacity, storage, of lake Winnebago 21, 22
Cause of change in drainage of the basin of the Red River of the North 80
Cause of floods in the Red River of the North 85
Cause of the form of the drainage system of the Northwest 6
Cedars 36
Fall and power at 36
Little Chute and Rapid Croche, dams at 45
Chalk Hill rapids, Menominee river 61
Change in the drainage of the basin of the Red River of the North 79
Cause of the 80
General Warren's theory on the 80
Indications of the 80
Professor Winchell's theory on 80, 81
Channel navigation at Appleton 28
Characteristic features of Lower Fox river as a water-power stream 20-23
Character and distribution of the water-powers of the Northwest 4-6
Character and topography of the country in the Northwest 3
Character, geological, of Menominee River basin 57
Character, location, etc., of dams on Lower Fox river (table) 44
Character of the country along the Saint Louis river 71
Character of the soil of the Northwest 4
Cheap form of coffer-dam on Lower Fox river 52
Chief tributaries of Saint Louis river (table) 72
Classification of the—
Lakes of the Northwest 11, 12
Powers of the Lower Fox river 19
Class, first, of lakes of the Northwest 12
Class, second, of lakes of the Northwest 12
Class, third, of lakes of the Northwest 12
Clearwater river 91
Climatic effects on flow of streams of the Northwest 7, 8
Coffer-dam on Lower Fox river, cheap form of 52
Company, Canal, Green Bay and Mississippi 20
Company, Water-Power, of Saint Louis river 75
Power owned by 75
Comparison of different sections of the Red River of the North 93
Comparison of lakeless with reservoir streams of the Northwest in regard to flow 10, 11
Comparison of the upper portion of the Red River of the North with the Bois de Sioux river 92
Conditions affecting flow of the streams of the Northwest 7-13
Conditions, legal, of the water-power of the Lower Fox river 19, 20
Construction of dam on the Sheyenne river 92
Constructions and dams on Lower Fox river, description of 44-52
Constructions, miscellaneous, on Lower Fox river 52
Countries, mountainous and level, effects on flow of streams of the Northwest 8
Country along the Saint Louis river, character of the 71
Country south of lake Superior 3
Country surrounding Wolf river 52
Course, ancient, of Upper Fox river 54
Crookston on Red Lake river—
Power at 90
Plan of improvement at 90, 91
Unimproved power above 91
Cross-section of the basin of the Red River of the North 82, 83
Cultivation, prairie, effects of, on the flow of streams of the Northwest 9
Cut-offs on the Upper Fox river 54

D.

Dam at—
Depère 45
Grand Kaukauna 45
Little Kaukauna 50
Dam at—Continued. Page.
Menasha 50
Middle level, Appleton 50, 51
Middle level, Appleton, method of building 51
Upper level, Appleton 45
Dam on the Sheyenne river, construction of 92
Dams and other constructions on Lower Fox river, description of 44-52
Dams at—
Cedars, Little Chute, and Rapid Croche 45
Lower level, Appleton, and at Neenah 45
Dams, government, location of, on the lower Fox river (table) 20
Dams on—
Lower Fox river, location, character, etc., of (table) 44
Menominee river, method of building 67
The Menominee river 65-67
Data concerning the large lakes of the Northwest (table) 10
Dayton to Fergus Falls, Red River of the North from 87
Depère 44
Depère—
Dam at 45
Fall and power at 44
Description—
General, of the basin of the Red River of the North 82, 83
Of dams and other constructions on Lower Fox river 44-52
Of lake Winnebago 21
Of lumber business of region north of Lower Fox system 55, 56
Of Milwaukee river (table) 67
Of Manitowoc river (table) 68
Of Sheboygan river (table) 68
Of the Lower Fox river 15-52
Of the Red River of the North in the hill country or water-power region 87
Of the water-powers along the Lower Fox river 23-52
Difference between the eastern and western tributaries of the Red River of the North, explanation of 92
Different levels of Fergus Falls, heads and ordinary low-water powers at the (table) 88
Different sections of the Red River of the North, comparison of 93
Dimensions of drainage basin of Menominee river 57
Discharge from Wisconsin river 54, 55
Discharges, low-water, lengths, drainage areas, and power of tributaries of Menominee river (table) 63
Discussion, physical, of the Lower Fox drainage basin 17
Distances and elevations along Lower Fox river from mouth to near Portage (table) 54
Distances and fall in Goose River rapids (table) 85
Distances, drainage areas, low-water volume, and power at different places on Menominee river (table) 58
Distribution and character of the water-powers of the Northwest 4-6
Distribution of—
Annual precipitation, in inches, of basin of Red River of the North and western drainage area of lake Michigan (table) 8
Fall of the Red River of the North in the hill country or water-power region 87
Lakes in Rainy Lake region and northern shore of lake Superior (table) 10
Lakes of the Northwest, according to drainage basins 9, 10
Lakes of the Northwest, according to state boundaries (table) 9
Lakes on southern shore of lake Superior (table) 10
Lakes on western shore of lake Michigan (table) 10
Precipitation on the western drainage area of lake Michigan 15
Timber in the Northwest 3
Water-powers of the Northwest 5
Division, twofold, hydrographical, of the basin of the Red River of the North 83, 84
Drainage and areas of drainage basins of the Northwest, system of 1, 2
Drainage area, western, of lake Michigan 13-68
Drainage area, western, of lake Michigan 5
Distribution of the precipitation on the 15
General remarks on the 13-15
Records of precipitation and temperature for the (table) 15
Drainage areas—
Distances, low-water volume, and power at different places on Menominee river (table) 58
Of lake and river basins of the Northwest (table) 1
Rainfall, tributary streams, etc., of basin of the Red River of the North, tables of 92, 93

Drainage basin— Page.
Lower Fox, physical discussion of the 17
Lower Fox river, geological history of the 17-19
Menominee river, dimensions of 57
Red River of the North, glacial action on the 79, 80
Red River of the North, physical geology of the 79
Drainage basins—
Distribution of lakes of the Northwest according to 9, 10
Of lake Michigan, western, areas of (table) 14
Of the Northwest, areas of, system of drainage 1, 2
Drainage, lengths, areas, low-water discharges, and power of tributaries of Menominee river (table) 63
Drainage of the basin of the Red River of the North, change in the 79
General Warren's theory on the change in 80
Professor Winchell's theory on the change in the 80, 81
Drainage of the Lower Fox basin, system of 17
Drainage system of the Northwest, cause of the form of the 6
Drought and freshet, times of, in regard to effect on flow of streams of Northwest 8

E.

Eastern and western tributaries of the Red River of the North, explanation of difference between 92
Edwards and Meade power at Grand Kaukauna 40
Effect of freshets from the Wolf and Upper Fox rivers on lake Winnebago 22
Effects, climatic, on flow of streams of the Northwest 7, 8
Effects of mountainous and of level countries on flow of streams of the Northwest 8
Effects of prairie cultivation on the flow of streams of the Northwest 9
Elevations and distances along Lower Fox river from mouth to near Portage (table) 54
Elevations in the basin of the Red River of the North (table) 83
Elevations of water-shed line of the Northwest 2
Entrance of the Red River of the North to the hill country, east of Breckinridge 84-87
Estimate of flow of Menominee river from the rainfall 58, 59
Estimated power of Milwaukee, Sheboygan, and Manitowoc rivers 68
Estimated theoretical power and principal rapids on Menominee fall (table) 62
Estimation of flow of Saint Louis river from the rainfall 72, 73
Expansion of lake Michigan 18
Explanation of the difference between the eastern and western tributaries of the Red River of the North 92

F.

Facilities—
Freighting, of Appleton 28
Transportation, of the region of the Red River of the North 79
Transportation, of Saint Louis river 71
Transportation, of the valley of the Lower Fox river 16, 17
Fall and distances in Goose River rapids (table) 85
Fall and power at—
Cedars 36
Depère 44
Grand Kaukauna 39
Little Chute 36, 37
Little Kaukauna 42
Lower level at Appleton 33
Neenah and Menasha 24
Rapid Croche 41
The Middle level at Appleton 31
Upper level at Appleton 29
Fall and power of the rapids of Saint Louis river 75
Fall of the—
Menominee river 59
Red Lake river 90
Red River of the North in the hill country or water-power region, distribution of the 87
Falls, Big Quinnesec, Menominee river 60, 61
Falls, Fergus—
First fall at 88
Location of the power of the Red River of the North above the 88
The Red River of the North above 88
Falls, Little Quinnesec, Menominee river 61
Falls, Pamena, Menominee river 61
Falls, Sturgeon, Menominee river 61
Falls, Twin, of Menominee river 59

Features— Page.
Characteristic, of Lower Fox river as a water-power stream 20-23
Favorable to water-power on Lower Fox river 23
Main topographical, of Menominee River basin 58
Modern surface, of the Northwest, effect of glacial age on 6
Fergus Falls 87, 88
First fall at 88
Fourth and fifth falls at 88
Heads and ordinary low-water powers at the different levels of (table) 88
Location of the power of the Red River of the North above the 88
Location of the town of 88
Second fall at 88
The Red River of the North above 88
Third fall at 88
Field for manufacturing in region north of Lower Fox River system 56
Filling, gradual, of the lakes of the Northwest 13
First class of lakes of the Northwest 12
First fall at Fergus Falls 88
Fissured rock, influence in reducing flow of streams of the Northwest 9
Floods in the Red River of the North and their cause 85
Floodwood to Cloquet, power of Saint Louis river from 73
Flow and power of the—
Red Lake river 90
Red River of the North in the hill country or water-power region 87
Flow of—
Menominee river from rainfall, estimate of 58, 59
Saint Louis river, estimation of, from the rainfall 72, 73
Streams, impossibility of accurate calculations of 7
Flow of streams of the Northwest—
Action of woodland on the 9
Climatic effects on 7, 8
Effects of mountainous and of level countries on 8
Effects of prairie cultivation on the 9
Influence of fissured rock in reducing 9
Influence of sand and gravel beds on 8
Influence of swamps in maintaining 11
Times of freshet and drought, effect on 8
Flow of streams, value of lakes of the Northwest in regulating the 9, 10
Flow of the—
Lower Fox river and the water-power 20
Lower Fox river, uniformity of 21
Red River of the North in the hill country or water-power region, uniformity of 87
Streams of the Northwest and conditions affecting it 7-13
Streams of the south shore of lake Superior in Wisconsin (table) 76
Wolf river 53
Fluctuation of Lower Fox river due to the mills 22, 23
Fourth and fifth falls at Fergus Falls 88
Fox river, lower—
Artificial reservoirs of the 22
Basin of the 14
Characteristic features of, as a water-power stream 20-23
Cheap form of coffer-dam on 52
Classification of the powers of the 19
Description of dams and other constructions on 44-52
Description of the 15-52
Description of the water-powers along the 23-52
Distances and elevations along, from mouth to near Portage (table) 54
Features favorable to water-power on 23
From Grand Kaukauna down to Rapid Croche 41
From Little Kaukauna down to Depère 43
From Lower level at Appleton down to Cedars 35
From Rapid Croche down to Little Kaukauna 42
Flow of the, and the water-power 20
Fluctuation of, due to the mills 22, 23
From Neenah and Menasha down to Appleton 27
Legal conditions of the water-power of the 19, 20
Legal history of the water-power of the 19
Location, character, etc., of dams on (table) 44
Location of government dams on the (table) 20
Location of the available powers of the (table) 21
Miscellaneous constructions on 52
Natural productions of the region of the 16
Railroad system of the valley of the 16
Rates of lease of powers on the 19, 20
Resources of the region of the 16

Fox river, lower—Continued. Page.
System, description of lumber business of region north of the..... 55, 56
System, field for manufacturing in region north of..... 56
System, iron mining in region north of..... 56
System of drainage of the basin of the..... 17
System, rivers of the region north of the..... 55–68
Transportation facilities of the valley of the..... 16, 17
Tributaries of..... 52–55
Uniformity of flow of the..... 21
Waterways of the valley of the..... 16
Fox river, Upper..... 54, 55
Ancient course of..... 54
Cut-offs on..... 54
Mills on..... 54
Tributaries of..... 55
Fox River valley—
Glacial action in the..... 18
Peculiarity of the..... 17
Freighting facilities of Appleton..... 28
Freightage, means of, at Little Chute..... 38
Freshet and drought, times of, in regard to effect on flow of streams of Northwest..... 8
Freshets from the Wolf and Upper Fox rivers, effect of, on lake Winnebago..... 22

G.

General description of the basin of the Red River of the North..... 82, 83
General remarks on the—
Red River of the North..... 79
Western drainage area of lake Michigan..... 13–15
Rivers of the western portion of lake Superior..... 68–75
Water-power of the northwestern states..... 1–13
General Warren's theory on the change in drainage of the basin of the Red River of the North..... 80
Geographical position of Saint Louis river, importance of the..... 70
Geological character of Menominee River basin..... 57
Geological history of—
Green Bay and Lake Winnebago valley..... 18
The ancient valley of the Wolf river..... 18
The drainage basin of the Lower Fox river..... 17–19
Geological structure of the basin of the Red River of the North..... 81–82
Geology of the region of the Northwest in its bearings on the water-powers..... 6, 7
Geology, physical, of the drainage basin of the Red River of the North..... 79
Glacial action in the Fox River valley..... 18
Glacial action on the drainage basin of the Red River of the North..... 79, 80
Glacial age, effect on modern surface features of the Northwest..... 6
Goose River rapids—
Distances and fall in (table)..... 85
Water-power of..... 85–87
Government dams on the Lower Fox river, location of (table)..... 20
Gradual filling of the lakes of the Northwest..... 13
Grand Kaukauna..... 38–41
Dam at..... 45
Edwards and Meade power at..... 40
Fall and power at..... 39
Kaukauna Water-power Company at..... 39, 40
Proposed improvements at..... 40, 41
Ship-canal at..... 39
Grand Rapids—
Menominee river..... 62
Power of Saint Louis river at..... 74
Gravel and sand beds, influence on flow of streams of the Northwest..... 8
Green Bay and Lake Winnebago valley, geological history of..... 18
Green Bay and Mississippi Canal Company..... 20

H.

Heads and ordinary low-water powers at the different levels of Fergus Falls (table)..... 88
Hill country east of Breckinridge, entrance of Red River of the North to the..... 84–87
Hill country or water-power region—
Description of the Red River of the North in the..... 87
Distribution of the fall of the Red River of the North in the..... 87
Flow and power of the Red River of the North in the..... 87
Uniformity of flow of the Red River of the North in the..... 87
History, geological— Page.
Of Green Bay and Lake Winnebago valley..... 18
Of the ancient valley of the Wolf river..... 18
Of the drainage basin of the Lower Fox river..... 17–19
History, legal, of the water-power of the Lower Fox river..... 19
History of the Middle level at Appleton..... 31
Hyde and Harriman canal at Lower level, Appleton..... 34, 35
Wooden bulkheads of..... 52
Hydrographical division, twofold, of the basin of the Red River of the North..... 83, 84
Hydrography, ancient, of the Northwest..... 2

I.

Importance of the geographical position of Saint Louis river..... 70
Impossibility of accurate calculations of flow of streams..... 7
Improved powers on Pelican river..... 89
Improvement at Crookston on Red Lake river, plan of..... 90, 91
Improvement, proposed, on the Saint Louis river..... 75
Improvements possible at Little Chute..... 38
Improvements, proposed, at Grand Kaukauna..... 40, 41
Indications of the change in drainage in the basin of the Red River of the North..... 80
Influence of fissured rock in reducing flow of streams of the Northwest. 9
Influence of sand and gravel beds on flow of streams of the Northwest.. 8
Influence of swamps in maintaining flow of streams of the Northwest... 11
Influence of the rock strata on Menominee river..... 57, 58
Influence, relative, of metamorphic and sedimentary rocks on the streams of the Northwest..... 7
Inlets, lakes of the Northwest without..... 12
Interests, lumber, along the Saint Louis river..... 71
Iron mining in region north of Lower Fox River system..... 56

K.

Kaukauna Water-power Company, at Grand Kaukauna..... 39, 40
Knife Falls to Thomson, power of Saint Louis river from..... 74

L.

Lake and river basins of the Northwest, drainage areas of (table)..... 1
Lakeless with reservoir streams of the Northwest, comparison of, in regard to flow..... 10, 11
Lake Michigan—
Areas of western drainage basins of (table)..... 14
Distribution of the precipitation on the western drainage area of.. 15
Expansion of..... 18
The western drainage area of, general remarks on..... 13–15
The western drainage area of, records of precipitation and temperature for (table)..... 15
Western drainage area of..... 5
Western shore of, distribution of lakes on (table)..... 10
Lake, Red..... 90
Lake Superior—
Country south of..... 3
Flow of the streams of the south shore of, in Wisconsin (table)..... 76
General remarks upon rivers of the western portion of..... 68–75
Northern shore of, and Rainy Lake region, distribution of lakes on (table)..... 10
Proposed canal to connect with the Red River of the North..... 71
Region..... 3
Rock and soil of the south shore of, in Wisconsin..... 76
Rivers of the south shore of, in Wisconsin..... 76–78
Southern shore of, distribution of lakes on (table)..... 10
Streams of the western portion of..... 5, 6
Topography of the south shore of, in Wisconsin..... 76
Lake Winnebago—
Description of..... 21
Effect of freshets from the Wolf and Upper Fox rivers on..... 22
Origin of..... 18
Storage capacity of..... 21, 22
Springs in..... 22
Lake Winnebago valley and Green Bay, geological history of..... 18
Lakes, distribution of—
In drainage basin of Red River of the North (table)..... 10
In drainage basin of Upper Mississippi river (table)..... 9
On northern shore of lake Superior and Rainy Lake region (table). 10
On southern shore of lake Superior (table)..... 10
On western shore of lake Michigan (table)..... 10
Lakes, Minnesota, origin of the..... 6

Page.
Lakes of the basin of the Red River of the North 84
Lakes of the Northwest—
Classification of the 11, 12
Data concerning the larger (table) 10
Distribution of, according to drainage basins 9, 10
Distribution of, according to state boundaries (table) 9
Gradual filling of the 13
Of first class 12
Of second class 12
The larger, data concerning the (table) 10
Third class of 12
Value in regulating the flow of streams 9, 10
Without inlets 12
Lease of powers on the Lower Fox river, rates of 19, 20
Legal conditions of the water-power of the Lower Fox river 19, 20
Legal history of the water-power of the Lower Fox river 19
Lengths, drainage, areas, low-water discharges, and power of tributaries of Menominee river (table) 63
Level and mountainous countries, effects on flow of streams of the Northwest 8
Level, Lower, at Appleton 33-35
Level, Middle, at Appleton 30-33
Level, Upper, at Appleton 28-30
Levels, different, of Fergus Falls, heads and ordinary low-water powers at the (table) 88
Limits of the basin of the Red River of the North 82
Little Chute 36-38
Fall and power at 36, 37
Means of freightage at 38
Possible improvements at 38
Rapid Croche and Cedars, dams at 45
Little Kaukauna 42
Dam at 50
Fall and power at 42
Little Quinnesec falls, Menominee river 61
Location, character, etc., of dams on Lower Fox river (table) 44
Location of—
Available powers of the Lower Fox river (table) 21
Government dams on the Lower Fox river (table) 20
Power of the Red River of the North above Fergus Falls 88
Town of Fergus Falls 88
Long pier at Upper level at Appleton 29, 30
Lower and upper sections of the Saint Louis River basin 71, 72
Lower dam on Menominee river 65-67
Lower Fox basin, system of drainage of the 17
Lower Fox drainage basin, physical discussion of the 17
Lower Fox river—
Artificial reservoirs of the 22
Basin of the 14
Characteristic features of, as a water-power stream 20-23
Cheap form of coffer-dam on 52
Classification of the powers of the 19
Description of dams and other constructions on 44, 52
Description of the 15-52
Description of the water-powers along the 23-52
Distances and elevations along, from mouth to near Portage (table) 54
Features favorable to water-power on 23
Flow of the, and the water-power 20
Fluctuation of, due to the mills 22, 23
From Grand Kaukauna down to Rapid Croche 41
From Little Kaukauna down to Depère 43
From Lower level at Appleton down to Cedars 35
From Neenah and Menasha down to Appleton 27
From Rapid Croche down to Little Kaukauna 42
Geological history of the drainage basin of the 17-19
Legal conditions of the water-power of the 19, 20
Legal history of the water-power of the 19
Location, character, etc., of dams on (table) 44
Location of government dams on the (table) 20
Location of the available powers of the (table) 21
Miscellaneous constructions on 52
Natural productions of the region of the 16
Railroad system of the valley of the 16
Rates of leases of powers on the 19, 20
Resources of the region of the 16

Lower Fox river—Continued. Page.
System, description of lumber business of region north of 55, 56
System, field for manufacturing in region north of 56
System, mining iron in region north of 56
Transportation facilities of the valley of the 16, 17
Tributaries of 52-55
Uniformity of flow of the 21
Waterways of the valley of the 16
Lower level at Appleton 33-35
Dams at, and at Neenah 45
Fall and power at 33
Hyde and Harriman canal at 34, 35
West-shore race at 34
Wooden bulkheads of Hyde and Harriman canal 52
Lower section of Saint Louis River basin, rock of the 72
Low-water discharges, lengths, drainage, areas, and power of tributaries of Menominee river (table) 63
Low-water powers, ordinary, and heads at the different levels of Fergus Falls (table) 88
Low-water volume, drainage areas, distances, and power at different places on Menominee river (table) 58
Lumber interests along the Saint Louis river 71
Lumber business of region north of Lower Fox system, description of 55, 56

M.

Main topographical features of Menominee River basin 58
Manitowoc, Milwaukee, and Sheboygan rivers 67, 68
Estimated power of 68
Manitowoc river, description of (table) 68
Manufacturing in region north of Lower Fox River system, field for 56
Marinette, rapids at, Menominee river 62
Mean precipitation in rain and melted snow and temperature at places in basin of the Red River of the North (table) 93
Means of freightage at Little Chute 38
Menasha 24
Menasha and Neenah, fall and power at 24
Menasha, dam at 50
Menominee river 57-67
And its power, volume of 58, 59
Bad Water rapids of 59
Big Quinnesec, falls of 60, 61
Chalk Hill rapids of 61
Dams upon the 65-67
Dimensions of drainage basin of 57
Distances, drainage areas, low-water volume, and power at different places on (table) 58
Estimate of flow of, from rainfall 58, 59
Fall of the 59
Grand rapids of 62
Influence of rock strata on 57, 58
Lengths, drainage, areas, low-water discharges, and power of tributaries of (table) 63
Little Quinnesec falls of 61
Lower dam on 65-67
Middle dam on 65
Nose Peak rapids of 61
Pamena falls of 61
Rapids at Marinette 62
Rapids of the 59-62
Sand Portage rapids of 61
Schappee's rifts of 62
Sixty-island rapids 62
Sturgeon falls of 61
Tributaries of 63, 64
Twin falls of 59
Twin Island rapids of 62
Upper dam on 65
Utilized power upon 63
White rapids of 62
Menominee River basin 14
Geological character of 57
Main topographical features of 58
Menominee River fall, principal rapids, and estimated theoretical power on (table) 62
Mequacumecum river 64

Page.

Metamorphic and sedimentary rocks on the streams of the Northwest, relative influence of ... 7
Method of building dam at Middle level, Appleton ... 51
Method of building dams on Menominee river ... 67
Michigamme river ... 64
Michigan, lake—
Areas of western drainage basins of (table) ... 14
Distribution of the precipitation on the western drainage area of ... 15
Expansion of ... 18
The western drainage area of ... 13–68
The western drainage area of, general remarks on ... 13–15
The western drainage area of, records of precipitation and temperature for (table) ... 15
Western drainage area of ... 5
Western shore of, distribution of lakes on (table) ... 10
Middle dam on Menominee river ... 65
Middle level at Appleton ... 30–33
Dam at ... 50, 51
Method of building dam at ... 51
Basin at ... 32
Fall and power at ... 31
History of the ... 31
North-shore race at ... 31, 32
West's canal at ... 32, 33
Mills, fluctuation of the Lower Fox river due to the ... 22, 23
Mills on Upper Fox river ... 54
Mills on Wolf river ... 53
Milwaukee river—
Description of (table) ... 67
Peculiarity of the ... 68
Milwaukee, Sheboygan, and Manitowoc rivers ... 67, 68
Estimated power of ... 68
Mining, iron, in region north of Lower Fox River system ... 56
Minnesota lakes, origin of the ... 6
Miscellaneous constructions on Lower Fox river ... 52
Mississippi and Green Bay Canal Company ... 20
Mississippi basin, Upper ... 5
Mississippi river, Upper, drainage basin, distribution of lakes in (table) ... 9
Modern surface features of the Northwest, effect of glacial age on ... 6
Montreal river ... 78
Mountainous and level countries, effects on flow of streams of the Northwest ... 8

N.

National boundary, tributaries of the Red River of the North down to the (table) ... 93
Natural productions of the region of the Lower Fox river ... 16
Navigation channel at Appleton ... 28
Nemadji river ... 78
Neenah ... 24–27
Neenah and Lower level at Appleton, dams at ... 45
Neenah and Menasha, fall and power at ... 24
North, Red River of the, distribution of lakes in drainage basin of (table) ... 10
North-shore race—
At Middle level at Appleton ... 31, 32
At Upper level at Appleton ... 29
Northwest—
Action of woodland on flow of streams of the ... 9
Amount of aqueous precipitation in the ... 7
Ancient hydrography of the ... 2
Areas of drainage basins of the, system of drainage ... 1, 2
Cause of the form of the drainage system of the ... 6
Character and distribution of the water-powers of the ... 4–6
Character and topography of the country in the ... 3
Character of the soil of the ... 4
Classification of the lakes of the ... 11, 12
Climatic effects on flow of streams of the ... 7, 8
Comparison of lakeless with reservoir streams of the, in regard to flow ... 10, 11
Data concerning the larger lakes of the (table) ... 10
Distribution of lakes of the, according to drainage basins ... 9, 10
Distribution of lakes of the, according to state boundaries (table) ... 9
Distribution of the timber in the ... 3
Distribution of the water-power of the ... 5
Drainage areas of lake and river basins of the (table) ... 1

Northwest—Continued. Page.

Effect of glacial age on modern surface features of the ... 6
Effects of mountainous and level countries on flow of streams of the ... 8
Effects of prairie cultivation on the flow of streams of the ... 9
Elevations of water-shed line of the ... 2
First class of lakes of the ... 12
Flow of the streams of the, and conditions affecting it ... 7–13
Geology of the region of the, in its bearings on the water-powers ... 6, 7
Gradual filling of the lakes of the ... 13
Influence of fissured rock in reducing flow of streams of the ... 9
Influence of sand and gravel beds on flow of streams of the ... 8
Influence of swamps in maintaining flow of streams of the ... 11
Lakes of the, value in regulating the flow of streams ... 9, 10
Lakes of the, without inlets ... 12
Prairie region of the ... 3, 4
Principal line of water-shed of the ... 1
Relative influence of metamorphic and sedimentary rocks on the streams of the ... 7
Second class of lakes of the ... 12
States, general remarks upon the water-power of the ... 1–13
Streams of the prairie region of the ... 4
Streams of the rugged region of the ... 4, 5
Third class of lakes of the ... 12
Times of freshet and drought, effect on flow of streams of the ... 8
Value of the water-power of the ... 5
Nose Peak rapids, Menominee river ... 61

O.

Ordinary low-water powers and heads at the different levels of Fergus Falls (table) ... 88
Origin of lake Winnebago ... 18
Origin of the Minnesota lakes ... 6
Otter Tail river ... 89
Power utilized on ... 89
Overflow from the Wisconsin river ... 17

P.

Pamena falls, Menominee river ... 61
Peculiarity of the Fox River valley ... 17
Peculiarity of the Milwaukee river ... 68
Pelican river ... 89
Improved powers on ... 89
Physical discussion of the Lower Fox drainage basin ... 17
Physical geology of the drainage basin of the Red River of the North ... 79
Pier, stone, at Appleton ... 45
Pine river ... 64
Pine River rapids ... 59
Places in basin of Red River of the North, mean precipitation in rain and melted snow and temperature at (table) ... 93
Plan of improvement at Crookston on Red Lake river ... 90, 91
Portion, upper, of the Red River of the North, comparison of, with the Bois de Sioux river ... 92
Position, geographical, of Saint Louis river, importance of the ... 70
Possible improvements at Little Chute ... 38
Power and fall at—
Cedars ... 36
Depère ... 44
Grand Kaukauna ... 39
Little Chute ... 36, 37
Little Kaukauna ... 42
Lower level at Appleton ... 33
Neenah and Menasha ... 24
Rapid Croche ... 41
The Middle level at Appleton ... 31
Upper level at Appleton ... 29
Power and fall of the Rapids of Saint Louis river ... 75
Power and flow of the—
Red Lake river ... 90
Red River of the North in the hill country or water-power region ... 87
Power and volume of the Menominee river ... 58, 59
Power at Crookston on Red Lake river ... 90
Power, distances, drainage areas, and low-water volume at different places on Menominee river (table) ... 58
Power, Edwards and Meade, at Grand Kaukauna ... 40
Power, estimated, of Milwaukee, Sheboygan, and Manitowoc rivers ... 68

Page.

Power, lengths, drainage areas, and low-water discharges of tributaries of Menominee river (table) 63
Power of Saint Louis river—
Table 73
Above Big White Face river 73
At Grand Rapids 74
From Big White Face to Floodwood river 73
From Floodwood to Cloquet river 73
From Knife falls to Thomson 74
Power of the Red River of the North above Fergus Falls, location of the. 88
Power on the Sheyenne river 92
Power owned by water-power company of Saint Louis river 75
Power, theoretical, estimated, and principal rapids on Menominee fall (table) 62
Power, unimproved, on Red Lake river above Crookston 91
Power, unused, at Upper level at Appleton 30
Power, utilized—
On Otter Tail river 89
On the Sheyenne river 92
Upon the Menominee river 63
Powers, available—
Of the Lower Fox river, location of the (table) 21
Of the Red Lake river 90
Powers, improved, on Pelican river 89
Powers of the Lower Fox river—
Classification of the 19
Rates of lease of 19, 20
Powers, ordinary low-water, and heads at the different levels of Fergus Falls (table) 88
Prairie cultivation, effects of, in the flow of streams of the Northwest... 9
Prairie region of the Northwest 3, 4
Streams of the 4
Precipitation—
And temperature for the western drainage area of lake Michigan, records of (table) 15
Annual, distribution of, in inches, of basin of Red River of the North and western drainage area of lake Michigan (table) 8
Aqueous, amount of, in the Northwest 7
On the western drainage area of lake Michigan, distribution of the. 15
Mean, in rain and melted snow, and temperature at places in basin of the Red River of the North (table) 93
Principal line of water-shed of the Northwest 1
Principal rapids on the Menominee fall, and estimated theoretical power (table) 62
Production of the region of the Red River of the North 79
Productions, natural, of the region of the Lower Fox river 16
Professor Winchell's theory on the change in drainage of the basin of the Red River of the North 80, 81
Proposed canal to connect lake Superior with the Red River of the North. 71
Proposed improvements—
At Grand Kaukauna 40, 41
On the Saint Louis river 75

R.

Race, north-shore—
At Middle level at Appleton 31, 32
At Upper level at Appleton 29
Race, west-shore, at Lower level at Appleton 34
Railroad system of the valley of the Lower Fox river 16
Rainfall—
Estimate of flow of Menominee river from 58, 59
Estimation of flow of Saint Louis river from the 72, 73
Tributary streams, drainage areas, etc., of basin of the Red River of the North, tables of 92, 93
Rainy Lake region and northern shore of lake Superior, distribution of lakes in (table) 10
Rapid Croche 41
Cedars and Little Chute, dams at 45
Fall and power at 41
Rapids—
At Marinette on Menominee river 62
Bad Water, Menominee river 59
Chalk Hill, Menominee river 61
Goose River, distances and fall in (table) 85
Goose River, water-power of 85–87
Grand, Menominee river 62

Rapids—Continued. Page.
Nose Peak, Menominee river 61
Of Saint Louis river 74, 75
Of Saint Louis river, fall and power of the 75
Of the Menominee river 59, 62
Pine River 59
Principal, on the Menominee fall, and estimated theoretical power (table) 62
Sand Portage, Menominee river 61
Sixty-Island, Menominee river 62
Twin Island, Menominee river 62
White, Menominee river 62
Rates of lease of powers on the Lower Fox river 19, 20
Records of precipitation and temperature for the western drainage area of lake Michigan (table) 15
Red lake 90
Red Lake river 89–91
Above Crookston, unimproved power on 91
Available powers of the 90
Fall of 90
Flow and power of 90
Plan of improvement at Crookston on 90, 91
Power at Crookston on 90
Red River of the North—
Above Fergus Falls 88
Above Fergus Falls, location of the power of the 88
And its drainage basin 79–93
Basin of the 5
Bed of the 85
Cause of change in drainage of the basin of the 80
Change in the drainage of the basin of the 79
Comparison of different sections of the 93
Comparison of the upper portion of, with the Bois de Sioux River.. 92
Cross-section of the basin of the 82, 83
Distribution of lakes in drainage basin of (table) 10
Elevations in the basin of the (table) 83
Explanation of the difference between the eastern and western tributaries of the 92
Floods in the, and their cause 85
From Dayton to Fergus Falls 87
General description of the basin of the 82, 83
General remarks on the 79
General Warren's theory on the change in drainage of the basin of the 80
Geological structure of the basin of the 81, 82
Glacial action on the drainage basin of the 79, 80
Indications of the change in drainage of the basin of the 80
In the hill country or water-power region, description of the 87
In the hill country or water-power region, distribution of fall of the. 87
In the hill country or water-power region, flow and power of the.. 87
In the hill country or water-power region, uniformity of flow of... 87
Lakes of the basin of the 84
Limits of the basin of the 82
Mean precipitation in rain and melted snow and temperature at places in basin of the (table) 93
Physical geology of the drainage basin of the 79
Proposed canal to connect with lake Superior 71
Production of the region of the 79
Professor Winchell's theory on the change in drainage of the basin of the 80, 81
Slope of the 85
Table 93
Timber in the basin of the 84
To the hill country east of Breckenridge, entrance of 84–87
Transportation facilities of the region of the 79
Tributaries of the 89–92
Tributaries of the, down to the national boundary (table) 93
Twofold hydrographical division of the basin of the 83, 84
Width of the 85
Region north of Lower Fox River system—
Description of lumber business of 55, 56
Field for manufacturing in 56
Mining iron in 56
Rivers of the 55–68
Region of the Lower Fox river—
Natural productions of the 16
Resources of the 16

Page.

Region of the Northwest, geology of the, in its bearings on the water-power 6, 7
Region of the Red River of the North—
Production of the 79
Transportation facilities of the 79
Region, prairie, of the Northwest 3, 4
Streams of the 4
Region, rugged, of the Northwest, streams of the 4, 5
Region, water-power or hill country—
Description of the Red River of the North in the 87
Distribution of fall of the Red River of the North in the 87
Flow and power of the Red River of the North in the 87
Uniformity of flow of the Red River of the North in the 87
Relative influence of metamorphic and sedimentary rocks on the streams of the Northwest 7
Remarks, general—
On the Red River of the North 79
On the western drainage area of lake Michigan 13–15
On rivers of the western portion of lake Superior 68–75
On the water-power of the northwestern states 1–13
Reservoir streams of the Northwest, comparison of lakeless with, in regard to flow 10, 11
Reservoirs, artificial, of the Lower Fox river 22
Resources of the region of the Lower Fox river 16
Rifts, Schappee's, Menominee river 62
River, Fox—
Glacial action in the valley of the 18
Peculiarity of the valley of the 17
River, Lower Fox—
Artificial reservoirs of the 22
Basin of the 14
Characteristic features of, as a water-power stream 20, 23
Cheap form of coffer-dam on 52
Classification of the powers of the 19
Description of dams and other constructions on 44–52
Description of the 15–52
Description of the water-powers along the 23–52
Geological history of the drainage basin of the 17–19
Features favorable to water-power on 23
Flow of the, and the water-power 20
Fluctuation of, due to the mills 22, 23
From Grand Kaukauna down to Rapid Croche 41
From Little Kaukauna down to Depère 43
From Lower level at Appleton down to Cedars 35
From Neena and Menasha down to Appleton 27
From Rapid Croche down to Little Kaukauna 42
Legal conditions of the water-power of the 19, 20
Legal history of the water-power of the 19
Location, character, etc., of dams on (table) 44
Location of government dams on the (table) 20
Location of the available powers of the (table) 21
Miscellaneous constructions on 52
Natural productions of the region of the 16
Railroad system of the valley of the 16
Rates of lease of powers on the 19, 20
Resources of the region of the 16
Transportation facilities of the valley of the 16. 17
Tributaries of 52–55
Uniformity of flow of the 21
Waterways of the valley of the 16
River, Menominee, basin 14
River, Upper Fox 54, 55
River, Wisconsin, overflow from 17
River, Wolf, geological history of the ancient valley of the 18
Rivers of the region north of Lower Fox River system 55–68
Rivers of the south shore of lake Superior in Wisconsin 76–78
Rivers of the western portion of lake Superior, general remarks upon 68–75
Rock and soil of the south shore of lake Superior in Wisconsin 76
Rock, fissured, influence in reducing flow of streams of the Northwest 9
Rock of the lower section of Saint Louis River basin 72
Rock strata, influence of, on Menominee river 57, 58
Rocks, metamorphic and sedimentary, on the streams of the Northwest, relative influence of 7
Rugged region of the Northwest, streams of the 4, 5

S.

Page.

Saint Louis river 70–75
Character of country along the 71
Chief tributaries of (table) 72
Description of tributaries of 72
Estimation of flow of, from the rainfall 72, 73
Fall and power of the rapids of 75
Importance of the geographical position of 70
Improvement proposed on 75
Lumber interests along 71
Power of, above Big White Face river 73
Power of, at Grand Rapids 74
Power of, from Big White Face to Floodwood river 73
Power of, from Floodwood to Cloquet river 73
Power of, from Knife Falls to Thomson 74
Power of (table) 73
Power owned by Water-Power Company of 75
Rapids of 74, 75
Rock of lower section of basin of 72
Special value of water-power of 70, 71
Transportation facilities of 71
Upper and lower sections of basin of 71, 72
Volume of 72
Water-Power Company of 75
Sand and gravel beds, influence on flow of streams of the Northwest 8
Sand Portage rapids, Menominee river 61
Schappee's rifts, Menominee river 62
Second class of lakes of the Northwest 12
Second fall at Fergus Falls 88
Sections—
Different, of the Red River of the North, comparison of 93
Upper and lower of the Saint Louis River basin 71, 72
Sedimentary and metamorphic rocks on the streams of the Northwest, relative influence of 7
Sheboygan, Milwaukee, and Manitowoc rivers 67, 68
Estimated power of 68
Sheboygan river, description of (table) 68
Shewano, Wolf river—
Above 53
Below 52, 53
Sheyenne river 91, 92
Construction of dam on 92
Power utilized on the 92
Power on the 92
Ship-canal at—
Grand Kaukauna 39
Upper level at Appleton 30
Sixty-island rapids, Menominee river 62
Slope of the Red River of the North 85
Soil and rock of the south shore of lake Superior in Wisconsin 76
Soil of the Northwest, character of the 4
Southern shore of lake Superior—
Distribution of lakes on (table) 10
In Wisconsin, flow of the streams of the (table) 76
In Wisconsin, rivers of the 76–78
South shore of lake Superior in Wisconsin, rock and soil of 76
In Wisconsin, topography of 76
Special value of water-power of Saint Louis river 70, 71
Springs in lake Winnebago 22
State boundaries, distribution of lakes of the Northwest according to (table) 9
Stone pier at Appleton 45
Storage capacity of lake Winnebago 21, 22
Sturgeon falls, Menominee river 61
Sturgeon river 64
Strata rock, influence of, on Menominee river 57, 58
Streams of the Northwest—
Comparison of lakeless with reservoir, in regard to flow 10, 11
Flow of the, and conditions affecting it 7–13
Streams of the prairie region of the Northwest 4
Streams of the rugged region of the Northwest 4, 5
Streams of the south shore of lake Superior in Wisconsin, flow of the (table) 76
Streams of the western portion of lake Superior 5, 6

Page.

Streams, tributary, drainage areas, rainfall, etc., of basin of the Red River of the North, tables of 92, 93
Structure, geological, of the basin of the Red River of the North 81, 82
Superior, lake—
Country south of 3
Flow of the streams of the south shore of, in Wisconsin (table) 76
General remarks upon rivers of the western portion of 68–75
Proposed canal to connect with the Red River of the North 71
Region 3
Rivers of the south shore of, in Wisconsin 76–78
Rock and soil of the south shore of, in Wisconsin 76
Southern shore of, distribution of lakes on (table) 10
Streams of the western portion of 5, 6
Topography of the south shore of, in Wisconsin 76
Surface features, modern, of the Northwest, effect of glacial age on 6
Surrounding country of Wolf river 52
Swamps, influence of, in maintaining flow of streams of the Northwest 11
System, drainage, of the Northwest, cause of the form of the 6
System, Lower Fox—
Description of lumber business of region north of 55, 56
Field for manufacturing in region north of 56
Mining iron in region north of 56
Rivers of the region north of 55–68
System of drainage and areas of drainage basins of the Northwest 1, 2
System of drainage of the Lower Fox basin 17

T.

Tables of tributary streams, drainage areas, rainfall, etc., of the basin of the Red River of the North 92, 93
Temperature and precipitation for the western drainage area of lake Michigan, records of (table) 15
Temperature and mean precipitation, in rain and melted snow, at places in basin of the Red River of the North (table) 93
Theoretical power, estimated, and principal rapids on Menominee falls (table) 62
Theory on the change in drainage of the basin of the Red River of the North—
General Warren's 80
Professor Winchell's 80, 81
Third class of lakes of the Northwest 12
Third fall at Fergus Falls 88
Timber in the basin of the Red River of the North 84
Timber in the Northwest, distribution of the 3
Times of freshet and drought, effect on flow of streams of Northwest 8
Topographical features, main, of Menominee River basin 58
Topography and character of the country in the Northwest 3
Topography of the south shore of lake Superior in Wisconsin 76
Town of Fergus Falls, location of the 88
Transportation facilities of—
Saint Louis river 71
The region of the Red River of the North 79
The valley of the Lower Fox river 16, 17
Tributaries—
Chief, of Saint Louis river (table) 72
Eastern and western, of the Red River of the North, explanation of difference between 92
Of Lower Fox river 52–55
Of Menominee river, lengths, drainage areas, low-water discharges, and power of (table) 63
Of the Menominee river 63, 64
Of the Red River of the North down to the national boundary (table) 93
Of the Red River of the North 89–92
Of Saint Louis river, description of 72
Of Upper Fox river 55
Of Wolf river 53
Tributary streams, drainage areas, rainfall, etc., of basin of the Red River of the North, tables of 92, 93
Twin falls of Menominee river 59
Twin Island rapids, Menominee river 62
Twofold hydrographical division of the basin of the Red River of the North 83, 84

U.

Page.

Uniformity of flow of the—
Lower Fox river 21
Red River of the North in the hill country or water-power region 87
Unimproved power on Red Lake river above Crookston 91
Unused power at Upper level at Appleton 30
Upper and lower sections of the Saint Louis River basin 71, 72
Upper dam on Menominee river 65
Upper Fox river 54, 55
Ancient course of 54
Cut-offs on 54
Mills on 54
Tributaries of 55
Upper level at Appleton 28–30
Dam at 45
Fall and power at 29
Long pier at 29, 30
Unused power at 30
North-shore race at 29
Ship-canal at 30
Upper Mississippi basin 5
Upper Mississippi river, drainage basin, distribution of lakes in (table) 9
Upper portion of the Red River of the North, comparison of, with the Bois de Sioux river 92
Utilized power on—
Otter Tail river 89
Sheyenne river 92
Menominee river 63

V.

Valley, Fox river—
Glacial action in the 18
Peculiarity of the 17
Valley, Lake Winnebago and Green Bay, geological history of 18
Valley of the Lower Fox river—
Railroad system of the 16
Transportation facilities of the 16, 17
Waterways of the 16
Value, special, of water-power of Saint Louis river 70, 71
Value of the water-powers of the Northwest 5
Volume of Saint Louis river 72
Volume of the Menominee river and its power 58, 59

W.

Water-power and flow of the Lower Fox river 20
Water-Power Company, Kaukauna, at Grand Kaukauna 39, 40
Water-Power Company, Saint Louis River 75
Power owned by 75
Water-power, features favorable to, on Lower Fox river 23
Water-powers, geology of the region of the Northwest in its bearings on the 6, 7
Water-power of—
Goose River rapids 85–87
Saint Louis river, special value of 70, 71
Lower Fox river, legal conditions of the 19, 20
Lower Fox river, legal history of the 19
Northwestern states, general remarks upon the 1–13
Water-power region or hill country—
Description of the Red River of the North in the 87
Distribution of fall of the Red River of the North in the 87
Flow and power of the Red River of the North in the 87
Uniformity of flow of the Red River of the North in the 87
Water-powers along the Lower Fox river, description of the 23–52
Water-powers of the Northwest—
Character and distribution of the 4–6
Distribution of the 5
Value of the 5
Water-shed line of the Northwest, elevations of the 2
Water-shed of the Northwest, principal line of 1
Waterways of the valley of the Lower Fox river 16
West-shore race at Lower level at Appleton 34
Western drainage area of lake Michigan 5
Distribution of the precipitation on the 15
General remarks on the 13–15
Records of precipitation and temperature for the (table) 15

	Page.
Western drainage basins of lake Michigan, areas of (table)	14
Western portion of lake Superior—	
General remarks upon rivers of the	68–75
Streams of the	5, 6
Western shore of lake Michigan, distribution of lakes on (table)	10
Western tributaries, and eastern, of the Red River of the North, explanation of difference between	92
West's canal at Middle level at Appleton	32, 33
White rapids, Menominee river	62
Width of the Red River of the North	85
Winnebago lake—	
Description of	21
Effect of freshets from the Wolf and Upper Fox Rivers on	22
Origin of	18
Springs in	22
Storage capacity of	21, 22
Wisconsin river—	
Discharge from	54–55
Overflow from	17
Without inlets, lakes of the Northwest	12
Wolf river	52, 53
Above Shawano	53
Below Shawano	52, 53
Flow of	53
Geological history of the ancient valley of the	18
Mills on	53
Surrounding country	52
Tributaries of	53
Woodland, action of, on the flow of streams of the Northwest	9
Wooden bulkheads of Hyde and Harriman canal at Lower level, Appleton	52

REPORT ON THE WATER-POWER

OF THE

MISSISSIPPI RIVER AND SOME OF ITS TRIBUTARIES.

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TABLE OF CONTENTS.

	Page.
GENERAL DISCUSSION OF THE MISSISSIPPI BASIN	1–10
GEOLOGY OF THE MISSISSIPPI BASIN	10–12
HYDROLOGY OF THE MISSISSIPPI BASIN	13–20
EXPLANATION AND DISCUSSION OF THE TABLES OF FLOW, RAINFALL, ETC	21–36
DESCRIPTION OF THE WATER-POWER SITES OF THE MISSISSIPPI RIVER	37–61
DISCUSSION OF THE TRIBUTARIES OF THE MISSISSIPPI	61–105
DESCRIPTION OF THE WATER-POWERS	105–118
TRIBUTARIES OF THE EAST SIDE OF THE MISSISSIPPI, FROM THE ROCK TO THE ILLINOIS RIVER	118–139
EASTERN TRIBUTARIES OF THE MISSISSIPPI, BETWEEN THE OHIO AND THE YAZOO	139, 140
EASTERN TRIBUTARIES OF THE MISSISSIPPI, FROM THE YAZOO TO THE MOUTH	140–142
RIVERS OF THE GULF OF MEXICO IN LOUISIANA AND MISSISSIPPI, AND THE TOMBIGBEE IN ALABAMA	143–151

LIST OF ILLUSTRATIONS.

	Page.
Sections of the Mississippi and Minnesota valleys	11
Map of River valley at junction of the Minnesota and Mississippi rivers	13
Curves of rainfall, flow, profile, etc., of the Mississippi river	35
Saint Anthony falls as they were	44
Saint Anthony falls as they are	44
Section of the bed of the east channel	50
Various engineering constructions, etc	54
Map of Rock Island	56
Penstock in use at Rock Island, Illinois	59
Drainage basin of the Minnesota river	64
Map of Brown's valley, Minnesota	65
Minnesota river at Granite Falls, Minnesota	70
Redwood Falls power, on Redwood river	73
Drainage basin of the Saint Croix river	75
The Saint Croix river, from above Taylor's Falls	75
Drainage basin of the Chippewa river, Wisconsin	81
Point creek dam, Chippewa river, Wisconsin	83
Map of the Chippewa falls water-power, Chippewa river	84
Drainage basin of the Black river	86
Drainage basin of the Wisconsin river	87
Drainage basins of the Cannon, Zumbro, Root rivers, etc	94
Drainage basin of the Rock river	101
Rock river, Illinois	109
Map of Rock river at Rockford, Illinois	110
Sketch map of Rock river at Oregon, Illinois	111
Map of Rock river at Grand Detour, Illinois	112
Sketch map of Rock river at Dixon, Illinois	112
Rock river at Sterling and Rock Falls, Illinois	113
Sketch map of Rock river at Milan, Illinois	116
Drainage basin of the Illinois river	119
Lake Michigan	121
Sketch map of the mills and hydraulic basin at Lockport, Illinois	123
Sketch map of the upper level on the Des Plaines river at Joliet, Illinois	124
Sketch map of the middle level on the Des Plaines river at Joliet, Illinois	124
Sketch map of the lower level on the Des Plaines river at Joliet, Illinois	125
Sketch map of Illinois river at Marseilles, Illinois	126
Sketch map of mills and hydraulic basin at Ottawa, Illinois	128
Sketch map of Kankakee river at Wilmington, Illinois	131
Section of upper dam of Kankakee Company, Kankakee river, Illinois	133
Sketch map of Kankakee river at Kankakee, Illinois	134
Drainage basins of the Yazoo, Big Black rivers, etc	139
Drainage basin of the Tombigbee river	143

REPORT ON THE WATER-POWER

OF THE

MISSISSIPPI RIVER AND OF SOME OF ITS TRIBUTARIES.

GENERAL DISCUSSION OF THE MISSISSIPPI BASIN.

COMPARISON OF THE MISSISSIPPI WITH OTHER RIVERS.

The gulf of Mexico extends far into the southern part of North America, almost washing the base of the Mexican ranges of the Cordillera. Its drainage area in the United States is about 57 per cent. of the whole area of the country. The drainage of very nearly three-quarters of this area, of about 1,725,980 square miles, tributary to the Gulf, is monopolized by the great river which is the subject of this report.

To say that the Mississippi drainage system is exceeded in extent by only two other rivers on the globe, does not convey much significance to those unaccustomed to the comparison of water-courses; but when we are told that over one-third of the entire area of the United States pours its tribute into this stream; that its mouth is at the southern shore-line of our country while its northern branches extend across the boundary into the British possessions; that the sun has been shining two hours and twenty minutes upon its waters in the east before it appears above the mountain peaks in which the far western branches rise; and that each year it carries to the sea 159 cubic miles of water—then it is that we form some idea of the vastness of a stream which can exceed the Mississippi.

There is something impressive in the fact, as you stand upon one of the bluffs overlooking the river, that there, before you, gathered in a single channel 3,000 feet wide, the melted snow and ice of the far north and the Rocky mountains mingle with the rains of the Alleghanies. The semi-tropical swamps, and the region lying far away toward the north, the mountains of the east and west, and the great rolling prairie, are all represented in this vast volume of water, rushing on with noiseless swiftness toward the sea.

As a matter of interest, a few facts such as can be gathered from the limited resources at hand regarding the large rivers of the globe are inserted:

Amazon river.—The Amazon is the greatest in every respect in the world, and has a drainage area of at least 2,264,000 square miles. It is from 3,500 to 4,000 miles long, and has 10,000 miles of navigation for large boats; 1,000 miles from the sea it is 4 miles wide; its average depth is 42 feet in the upper portion, and at the mouth it is 312 feet deep. The usual current is 3 miles per hour. The flood-rise is from 42 to 48 feet above the lowest level. The elevation, at a distance of 3,000 miles from the mouth, is only 210 feet above the sea, and the tide is observable 400 miles above the mouth. The average discharge has been estimated by Jean Jacques Élisée Reclus to be 2,458,026 cubic feet per second. (See *Van Nostrand's Magazine*, vol. 24, page 66.) Another estimate gives a discharge of 500,000 cubic feet per second at a point above the entrance of two large tributaries each over 800 miles long. It is impossible that both these estimates should be right. Because of the heavy rainfall in the tropics, the first amount is more likely to be correct.

Mississippi river.—The Mississippi has a drainage area estimated to be 1,261,000 square miles. Its length to the sources of the upper Mississippi is 2,616 miles. The distance by water from the sources of its great tributary, the Missouri, to the gulf of Mexico is 4,194 miles. The length of navigable waters is estimated to be 15,000 miles, but a large portion of this is closed during low stages of water. The average width in the lower half of its course is from one-half to three-quarters of a mile. The maximum depth of channel averages about 60 feet in the lower half of its river, increasing to 125 feet near the mouth. The maximum flood-level is about 52 feet above low

water on the lower half of the river, diminishing to 15 feet near the mouth. The source of the Mississippi is 1,680 feet above the sea-level. The tidal influence is not noticeable 300 miles from the mouth. The range of spring tide in the Gulf is 1.7 foot. The total discharge from the basin averages 675,000 cubic feet per second.

Rivers of Asia.—There are in Asia several rivers of grand dimensions, and the largest, the Obi, flowing north through Siberia, has a drainage area estimated to be 1,250,000 square miles.

The Yenesei, adjoining on the east, drains 1,041,000 square miles; and the Lena, just east of that, drains 787,000 square miles. Of the three rivers just mentioned, the Obi is the only one which is navigable for any distance.

The Yangtse Kiang drains from 550,000 to 750,000 square miles, and has an average flow of 770,397 cubic feet per second. The Hoang Ho and the Amoor each drain over 500,000 square miles, and the average discharge of the former is 116,000 cubic feet per second. (See *Van Nostrand's Magazine*, vol. 24, p. 63.) The Yangtse Kiang is the longest river of Asia, about 3,300 miles. The Yenesei is about 3,200 miles long, and the rest range from 1,500 to 3,000 miles in length.

The Ganges and Brahmapootra, in India, connect at their mouths, and together they drain an area of about 500,000 square miles. The Ganges, at 500 miles from the sea, has an average flow of 233,000 cubic feet per second. The length of the Ganges is about 1,500 miles. In the first 160 miles it falls 12,000 feet, and is then 1,024 feet above sea-level. The average discharge of the Ganges at Ghazapoor has been estimated at 203,485 cubic feet per second.

Rivers of Europe.—The Volga, which is the largest river of Europe, adjoins the Obi on the west. It has a drainage area of about 500,000 square miles, and is 2,500 miles long.

The Danube, the second river of Europe, has a drainage area of 300,000 square miles. The average flow is about 200,000 cubic feet per second.

Rivers of Africa.—The Nile and Congo are the largest rivers of Africa, and their sources are in the unexplored region in the interior of that continent. The drainage area of the Nile is said to be not less than 500,000 square miles, and 800,000 square miles are claimed by one authority for the Congo. The Nile is probably not less than 4,000 miles long, and its average discharge has been estimated at 130,032 cubic feet per second.

In comparing these few data concerning the great rivers of the globe, it must be remembered that hydrographic comparisons and hydrological comparisons are very different in their nature. Two rivers having equal drainage areas may be very unequal in their volumes, owing to differences in climate, rainfall, etc., as will presently be illustrated to a marked degree when mentioning the tributaries of the Mississippi itself. The Mississippi is probably the second river of the world in extent of drainage basin, being exceeded only by the Amazon. In volume of discharge, as in extent of area drained, the Amazon is truly an immense river, and there seems no reason to doubt the large estimate of flow given for it. Relatively to extent of basin, it is exceeded by some of the smaller rivers of the Mississippi basin.

Although no actual measurements of the discharge of the Obi are obtainable, there is every reason to believe that, in its region, where every thing is frozen solid most of the year, the precipitation and the volume of flow bear no comparison to the like factors of the Mississippi basin.

The two rivers which, after the Amazon (if the estimates made concerning them can be relied upon), exceed the Mississippi in volume although not in drainage area, are the Congo and the Yangtse Kiang. The amount of 1,800,000 cubic feet per second for the Congo was apparently an exceedingly rough approximation, based on assumed factors. The estimates for the Yangtse Kiang were made with more care, and the estimate of 770,000 cubic feet per second is probably of some value. This exceeds the average flow of the Mississippi by nearly 100,000 cubic feet per second, while the drainage area of the river is hardly more than one-half the area of the Mississippi basin.

THE BASIN OF THE MISSISSIPPI.

The sources of the Mississippi proper are between latitudes 47° and 48° north, and almost exactly in the center of the continent on an east-and-west line. Its general course is southward. The mouth is in latitude 29° north.

Form and location.—The basin, very irregular in outline, can best be described as an oblong, with the major axis 1,700 miles in length, running southeast from the northwestern portion of Montana, through Dakota, Nebraska, Missouri, and Tennessee, into the northwestern corner of the state of Alabama. On each side of this line the basin spreads out from 300 to 500 miles, while at the east there is a large protuberance from the general outline, extending to the Alleghany mountains. The total area of this basin is 1,240,039 square miles. This immense area includes, wholly or in part, 25 states and 5 territories, besides a small area in the British possessions. All the states and territories between the Alleghanies and the Rocky mountains contribute to the volume of the Mississippi. The eastern outline of the basin conforms roughly to the Atlantic coast; its mean distance from it being about 250 miles. The eastern and western outlines are determined by the two great systems of mountains, the Appalachian and the Cordilleras, which, from the physical laws attending their formation, coincide more or less closely with the coast-lines of the continent.

Hydrographical division of the basin.—The Mississippi is popularly considered to rise in Minnesota, and, for geographical purposes, this is a sufficient distinction; but in considering the Mississippi and its branches with

regard to the areas drained, and the actual volume of the streams, some further distinction is necessary. This will be made apparent by a glance at the map, and a comparison of the following data concerning the chief rivers of the basin.

The entire area may be divided into these four grand sections, in the following order of size: The Missouri basin, on the west; the basins of the Arkansas and Red rivers, on the west; the Ohio basin, on the east; the basin of the upper Mississippi.

The upper Mississippi is considered to extend to the mouth of the Missouri, and below that the river is called the lower Mississippi. Humphreys and Abbot, in beginning their report, state that the true Mississippi begins at the mouth of the Missouri—with what grounds we will be better enabled to judge after examining the data of the rivers.

In Humphreys and Abbot's report, which is considered the authority on the subject, is found this division of the basin:

Name of basin.	Area drained.	Average flow per second.	Annual discharge.
	Square miles.	*Cubic feet.*	*Cubic feet.*
Missouri	518,000	120,000	3,780,000,000,000
Ohio	214,000	158,000	5,000,000,000,000
Arkansas	189,000	63,000	2,000,000,000,000
Upper Mississippi	169,000	105,000	3,300,000,000,000
Red	97,000	57,000	1,800,000,000,000
Yazoo	13,850	43,000	1,350,000,000,000
Saint Francis	10,500	31,000	990,000,000,000
Small, direct tributaries	32,400	.....	.....

Relations of the upper Mississippi and the Missouri.—From this table it is seen that the Ohio river has the largest volume of flow; then comes the Missouri, and next the upper Mississippi. The question as to the continuation of the main drainage trunk lies evidently between the Missouri and the upper Mississippi. As regards extent of territory the Missouri can undoubtedly claim the prestige, for its basin is well-nigh half the entire drainage area, and it determines the form of the Mississippi basin, the major axis, already alluded to, lying nearly in the general course of the Missouri. But, considering the actual sizes of the two streams, the Missouri loses ground; the discharge of the upper Mississippi is 87.5 per cent. of that of the Missouri, while its basin is only 32.6 per cent. of the Missouri basin. At this rate it would require only an addition of 9,320 square miles, or 5.5 per cent., to the drainage basin of the upper Mississippi to make its average flow exceed that of the Missouri. To some extent the upper Mississippi has a claim to distinction as being the continuation north of the general course of the river. The Missouri is a turbulent, rushing stream of muddy water, and with its swift current, carrying with it many logs and trees, presents a strong contrast to the quiet and placid upper Mississippi. Below the junction the united currents flow in a channel even narrower than that of the upper Mississippi, and consequently the stream assumes a character in which the preponderating influence attributed to the Missouri may be more apparent than real. It would seem that the situation is briefly this: If area drained and length of water-course are to be considered, the Missouri should be called the Mississippi; if consideration is to be taken of the volume of flow, together with the general course of the stream, the true Mississippi should be considered, as it is, to rise in Minnesota. It is also apparent that, for hydrological purposes, the rational method is to divide the river into the upper and lower Mississippi, and this distinction will be carried throughout this report.

In comparing the large rivers of the world, allusion was made to the great difference existing between the hydrographic and hydrological relations of rivers. This is brought out very plainly by the data for the rivers of the Mississippi basin, as indeed might be inferred from the great extent of country covered, and the climatic differences of different parts. The facts just mentioned, concerning the upper Mississippi and the Missouri, illustrate it; the dry, arid region, of which a large part of the Missouri basin consists, nearly gives the precedence to the upper Mississippi in point of flow, although the latter drains less than one-third the area included by the former. In like manner, the Ohio, with its basin of only 214,000 square miles, exceeds the discharge of the Missouri by 38,000 cubic feet per second. Again, the figures given show that the average flow per second per square mile of drainage area in the well-watered Yazoo basin is 3.1 cubic feet, while for the Missouri the average flow is only 0.23 cubic foot per second.

TOPOGRAPHICAL FEATURES OF THE BASIN.

As regards topography, the country included within the Mississippi system presents all varieties. Mountain and prairie, arid plain, and alluvial bottom teeming with vegetation, are all represented within its limits. The great extent, however, is very uniform in contour, and presents none of the grand features of a mountainous country. The Mississippi occupies the great basin lying between the two great mountain chains of North America. On the east, the sources of the only large tributary, the Ohio, take their rise among the ranges of the Appalachian system. On the west, the headwaters of the Missouri and the Arkansas are among the massive peaks of the Rocky

mountains. At the north, the sources of the upper Mississippi and the northern tributaries of the Missouri and the Ohio are limited by an indefinite line separating the basin from the regions of the great lakes and the Red river of the North; but no range of mountains forms the water-shed, and, in fact, some swamps and lakes drain indiscriminately in both directions.

West of the river.—The region lying between the foot-hills of the Rocky mountains and the Mississippi river may best be described as an immense undulating plain, sloping toward the south and east. Its elevation is from 4,000 to 6,000 feet above the sea at the base of the mountains, diminishing to less than 1,000 feet near the Mississippi. This area constitutes the great plains and the western portion of the prairie region.

East of the river.—East of the Mississippi the topography is not so distinctly prairie, especially south of the Ohio river, but is, nevertheless, not mountainous, except near the eastern water-shed of the basin. In Illinois, northern Indiana, and southern Michigan and Wisconsin are large extents of prairie; but eastward the country is much broken up by the streams, and southward, in eastern Kentucky and Tennessee, occur the Cumberland plateau and other table-lands, making a great diversity in the nature of the surface. Through Indiana and Ohio the soil is fertile and excellent for farming; but south and east of the Ohio river there is not that uniform richness of the land that is so remarkable in Illinois and the prairies of the west and northwest.

The average elevation above the sea is from 500 feet in southern Illinois and Indiana, rising to 800 feet in the northern portion of those states. The average elevation of the undulating surface of Ohio is about 1,000 feet. The surface in Tennessee and Kentucky varies from 300 feet above the sea near the Mississippi, to from 600 to 1,000 feet in the central portions. On the Cumberland plateau the height above sea-level averages about 3,000 feet. In the East Tennessee valley the elevation ranges from 600 to 2,000 feet.

Near the sources.—The country about the extreme sources of the Mississippi, far away in Minnesota and Wisconsin, is from 1,200 to 1,500 feet above the sea. As is already described in the "General Remarks upon the Water-power of the Northwest", there is one point where the water-shed of the Mississippi basin crosses the end of the lake Superior trough, which is only slightly elevated above that lake, or about 610 feet above the sea. This is lower than the altitude reached by the line of water-shed even in part of the state of Mississippi, adjoining the gulf of Mexico.

Staple products.—The Mississippi basin is the agricultural region of the United States, and its population of 21,821,254 is directly dependent upon the cultivation of the ground for its support. The mines of the West do very little to increase the wealth of the country in comparison with the products of the soil. According to the statistics of the Census of 1880, the value of the mineral product of the entire country but slightly exceeded the value of the agricultural products of the state of Illinois alone. The staple products of the land are wheat, Indian corn, tobacco, cotton, and sugar; in the western portion of the basin, and to some extent in the east, grazing is carried on extensively. In considering the distribution of these staples, the Mississippi valley may be roughly divided into zones belonging to the several crops, although they merge one into the other. The wheat belt extends from the vast prairie of the British possessions down into Illinois, the winter wheat not extending above southern Minnesota. Then comes the corn belt, more or less confused with the wheat region, and extending down about to Mississippi, although large quantities are raised in Texas. In southern Tennessee begins the cotton belt, which continues south to the Gulf coast. Along the delta of the Mississippi, in Louisiana, are sugar-cane plantations.

The Mississippi basin has rapidly increased in population within recent years, owing largely to the settlement of the western prairies. In 1870 the number of inhabitants was 16,431,855, and in 1880 it had increased to 21,821,254.

Navigation.—This rapid settlement has been at once the outgrowth and the cause of the great systems of railroads which cross the basin from east to west and are the principal channels of freightage for the products of the soil. The great river itself, with the larger branches, furnishes a grand system of internal navigation of great value to the country. The Mississippi basin is stated by one estimate to have 15,000 miles of navigable waters, of which the Missouri has 3,500 miles, and the Ohio has 5,000 miles. Over large portions of these distances, however, as already stated, navigation is impracticable in low stages of water. The route from Pittsburgh down the Ohio to the Mississippi is of great value, and at high stages the river is alive with "stern-wheelers", barges, and tow-boats, which carry the coal, oil, and iron of the east, to the states reached by the Mississippi. The trade down the river to New Orleans, and especially to Saint Louis, is large and of increasing importance. The navigation of the Missouri is very difficult, owing to the uncertainty of the channel; and the upper portion of the stream is now used to only a small extent for trade.

DISCOVERY AND EARLY EXPLORATIONS OF THE MISSISSIPPI RIVER.

The first explorers of our continent were the Spaniards and the French; and it was fitting that the river which ranks first among its water-courses, whose very name signifies the "Father of Waters", should be discovered and its course explored by these earliest invaders of the New World.

SPANIARDS, 1541.—De Soto and his following of Spanish cavaliers started from the southern Atlantic coast in their fruitless search for the "El Dorado", and after tedious wanderings through the Gulf states, passing northwest through Alabama and Mississippi, they came out at last on the crest of the bluffs which form the east shore of the

Mississippi, near where Memphis now stands. It is thought that these men, as they stood above the broad flood of the Mississippi on that day in June, 1541, were the first Europeans to gaze upon its waters. De Soto and his men were, of course, sadly disappointed in their hopes concerning the discovery of an El Dorado. Instead of plenty and peace, they found unending hardships; their visions of a fountain of life (conjectured to be caused by Indian rumors concerning the hot springs of Arkansas, toward which they were journeying) ended as visions always do; and after burying their leader beneath the waters of the stream, they fled down its rapid current, glad of the means it offered for escape.

THE FRENCH.—The discoveries of the Spaniards were in great part abandoned, and not until a century later was the region of the Mississippi again invaded. Then it was that the French explorations began, which, including the interests of domain, barter, and religious zeal, left a permanent impress upon the country, strongly apparent at the present time. In Mr. Francis Parkman's *History of the Great West* is an exceedingly interesting account of the early French possession, from which the following facts are gleaned:

Nicollet.—Jean Nicollet, a French interpreter, approached the Mississippi from the north. He heard of an Indian tribe to the westward, which traded with a tribe of men with smooth faces and no hair. Europe was endeavoring to find a western passage to the east, and what more natural than for him to suppose that these beardless men were the Chinese. He heard from the Indians that there was water communication to the west, and a great river; this, he concluded, must be the long-sought western passage, and he determined to find it. Accordingly he set out on the great lakes, ascended the Fox river, made the portage to the Wisconsin, and descended that wide stream to near the mouth. Nothing doubting that this led to the Pacific ocean, he returned.

Marquette, 1672.—On May 17, 1672, Marquette and Joliet started from Point Saint Ignace, on the straits of Michillimackinac, pursued Nicollet's route down the Wisconsin, and on June 17 entered the Mississippi, the first white men to reach its northern waters. Down its placid course they floated, until greatly terrified by the boiling, surging water of the Missouri river, which at that time was probably in flood from the melted snow of the Rocky mountains. Marquette wrote: "I never saw anything more terrific." Along the now turbulent stream their canoe was hurried, and they reached the mouth of the Arkansas river, where they stopped; and on July 17 began their return journey, confident that this great stream entered the gulf of Mexico. At the foot of the La Chine rapids of the Saint Lawrence, within sight of their final destination, Montreal, after months of arduous labor and many miles of travel, their canoe upset, and all their notes and maps were lost. Glad was Marquette, who wrote an account of the trip, to escape with his life.

Hennepin, 1680.—Father Hennepin, in 1680, was sent to explore the Mississippi; and, being taken captive by the Sioux Indians, was carried away by them in the very direction he wished to follow. He spent the winter in their lodges about Mille Lacs, on the upper Mississippi, and the following year was allowed to return. Hennepin was the first man to explore the Mississippi above the mouth of the Wisconsin, and to him is due the earliest description of Saint Anthony's Falls, the Owah-Menah, or the "Falling Water" of the Sioux.

La Salle, 1682.—La Salle next explored the Mississippi. Pursuing the course taken by Marquette and Joliet on their return trip, he started down the Illinois river; and on February 6, 1682, entered the great river. After waiting for the floating ice to disappear, this party too floated down the current, landed at the Arkansas, as their predecessors had done, and then, continuing their course, reached the gulf of Mexico. On a dry piece of ground near the mouth they planted a column bearing the French coat of arms, and on April 9, 1682, La Salle took formal possession, for Louis XIV, of the entire basin of the Mississippi and the region adjoining the Gulf, giving it the name of Louisiana.

Transfers of territory.—The French soon controlled this region by means of a line of frontier posts. Subsequently the part east of the Mississippi was ceded to Great Britain, and fell into the hands of the United States at the close of the Revolution. The western part went into the hands of Spain, then was returned to France and was sold by it to the United States in 1803.

Traces of the old-time rule and the Indians.—All along the course of the Mississippi the traces of the old-time rule are to be seen. On the lower part of the stream are to be noticed the influences of Spanish life, and all along its course are scattered the traces of French occupancy. The names of La Salle, Joliet, and Hennepin, of Nicollet, Dubuque, Duluth, and good old Père Marquette are familiar. Even the Saints are represented: Saint Paul, Saint Peter, Saint Louis, etc., are well-known names. The country about the extreme upper waters of the Mississippi was occupied by the fur-traders of the Northwest Company, and the Hudson Bay Company had many a quarrel with them about disputed territory. This was ended by the formation of the United States. The region of the upper Mississippi has been, until comparatively recent years, the scene of many bloody fights between the Sioux and the Chippewa Indians. Their boundary line ran through the state of Minnesota, cutting its eastern border on the lower Saint Croix. They, too, have left their mark in the present nomenclature. The beautiful names in which the state abounds are due to them. Minnesota, sky-tinted water; Minneopa; the famed falls of Minnehaha, Minnetonka, Owah-Menah, the falling water; and many other melodious terms are due to the Sioux. The wilder names to the northward, as Pokegama, Totogatic, etc., were given by the Chippewas, who yet exist there in considerable numbers. Their language abounds in names like Suskenobekouse, a small rapid; Tongamink, a slack-water; Kakawbekouls, etc. Their name for the present Mille Lacs was Missi-saugaigan, or Great Lake.

Names of the Mississippi.—The name Mississippi appears to be derived from the Algonquin language, which originated in the eastern part of the continent. It is found spelled in various ways, Messasipi, Messipi, Michisipi, etc., but according to Schoolcraft, the present name is a corruption, through French and then English handling, of the name Missi Sepe, meaning Great River, a word, as he remarks, much softer and more beautiful than the modern ending, *sippi*. Various names were given to the river by the early explorers, as Rivière de Buade, Rivière Colbert, and Rivière de la Conception; but all have finally given way, as they should, to the old Indian name.

GENERAL DESCRIPTION OF THE COURSE OF THE MISSISSIPPI.

In describing the basin of the Mississippi, the uniform, undulating surface of the basin was found to continue northward, unbroken by any mountain chain. Hence the river can not be considered a mountain stream. Its utmost sources are not more than 1,680 feet above the sea, although 2,616 miles distant from it. The Hauteur des Terres, a low range of sandy ridges of glacial origin in northern Minnesota, contains the birthplace of the Mississippi.

The source.—It springs from a sheet of water, one of the innumerable sparkling lakes which dot the surface of that region, called by Schoolcraft, who visited it on July 13, 1832, Itasca lake. The Chippewa name was Omoshkosh Sagaigon, and the French traders called it Lac la Biche. The length is about 4 miles, and the breadth exceeds nowhere half a mile. It is fed by trickling streamlets, none of which are over 2 miles in length. The surrounding country consists of low ridges of light sandy soil, largely covered with pine and intervening tamarack and cedar swamps. Mr. Schoolcraft, in his account of his trip, describes the voyage down the river from lake Itasca. From his account the following description is abstracted:

The outlet.—The outlet is about 10 or 12 feet wide, and from 12 to 18 inches deep. From the outlet the force of the current increases, and for 12 miles the stream is rapid and the turns are very abrupt. Next comes a savannah-like valley for 8 or 9 miles, in which the stream has a gentle current. Beyond this, the river is narrow and very rapid, over a rough bowlder bed, after which comes a second plateau, perhaps 9 miles long, succeeded by some easy rapids. Then come more savannahs, with a wide, winding channel; then short rapids, which, writes Schoolcraft, bring the river out of what may be called the Alpine passes. Then the stream takes a size easily navigated by canoes, and thus lake Bemidji is reached. Four miles above this lake the east branch comes in from the southward. This heads in lake Ossowa, only 6 miles from Itasca lake. Schoolcraft describes the east branch as "a thread wound along the savannah valley." Well up its course are rapids, aggregating perhaps 48 feet in descent.

Between lake Bemidji and Cass lake there are strong rapids, among which Schoolcraft counted ten principal ones. In this distance of about 145 miles, from the utmost sources to the outlet of Cass lake, the total fall is about 380 feet. The descent from lake Bemidji is 42 feet. From Cass lake to the outlet of Leech lake there is a good current, the total descent being about 44 feet, and the average width about 60 feet. Leech Lake river is nearly as large as the main river, and below it the width averages 100 feet. Below Leech Lake river to the falls of Pokegama the course of the river is exceedingly tortuous, in a prairie averaging 3 miles wide, bounded by low sand ridges, covered with yellow pine. The current is sluggish. Thus far the bed of the stream is entirely in glacial drift. The most prominent features are the low sand ridges with their covering of pine; the tamarack and cedar swamps; in places forests of elm, maple, and ash; and along the shallow valley, the rushes, wild rice, and rank grass. At Pokegama falls is met the first rock in place. Below Pokegama falls the current is good, with many rapids of small extent. The stream averages 300 feet wide down to the Crow Wing river (formerly called Rivière de Corbeau), and is less winding. The clay banks, at first 4 to 10 feet in height, gradually become higher. There are forests of elm, maple, birch, oak, and ash. We have now followed the river through fully the 180 degrees of a semicircle, which it has described from its source. The mouth of the Crow Wing, which enters from the west, is only 75 miles from Itasca lake, while the distance along the river from the sources is 450 miles. From this point the general course of the Mississippi is southeast for 475 miles. The Crow Wing is an important tributary, and increases the size of the stream materially. The average width down to Saint Anthony falls is stated by Schoolcraft to be 750 feet. There are several rapids, the chief being Little falls and Sauk rapids, formerly called Big falls. Many timbered islands occur; the banks are abrupt, of clay or sandy loam, and lead to natural meadows, 60 feet above the river. These contain a rank growth of grass interspersed with scrub oak, and were the favorite feeding-grounds of the buffalo.

Saint Anthony falls.—At Saint Anthony falls occurs a sudden break in the nature of the river. It pitches down a vertical fall and rapid, amounting to 75 feet in a half-mile, and, in so doing, leaves the prairie and clay banks for a channel between rocky bluffs of limestone and sandstone. These bluffs continue for many miles down the river, increasing to even 500 feet in height as the bed sinks below the general prairie level, and they give great variety and beauty to the scenery. Their sides are not vertical bare surfaces of rock, but the easily-eroded stone and drift have formed slopes well wooded or covered with grasses. Ten miles below Saint Anthony falls, the Minnesota river, formerly called the Saint Peter's river, enters from the west. It is the largest tributary thus far encountered, and below it the breadth of the stream is about 1,000 feet.

Below the Minnesota river.—From this point down to the mouth of the Missouri the general characteristics are the same—a broad, placid stream, with innumerable islands, which make the entire width occupied by the river average about one mile; varied scenery of the bluffs, now rugged and steep, now sloping away in beautifully wooded hills, several hundred feet high, to the prairie surface. In many places, especially where the tributaries enter, there are fertile flats between the river and the bluffs. Fifty-five miles below the Minnesota river is lake Pepin, an expansion of the river apparently caused by the immense quantities of sand brought down by the Chippewa river. It is 27 miles long and 2 or 3 miles wide.

The large tributaries are the Saint Croix, Chippewa, Wisconsin, Rock, and Illinois, on the east; and below the Minnesota river on the west, the Iowa and the Des Moines. Two exceptions occur to the otherwise placid character of the river. At Rock Island, 384 miles from Saint Paul, there are rapids over a succession of rocky chains extending across the river, and the descent is 20.4 feet in a distance of 12 miles. Again at Keokuk, 509 miles from Saint Paul, is the foot of the Des Moines rapids, where, in a distance of 11 miles, the river falls 21.85 feet over a rocky bed. These two rapids and those above Saint Anthony falls will be more fully described when the water-powers are considered.

This brings us to the end of what is known as the upper Mississippi, at a distance from the source estimated to be 1,204 miles.

THE LOWER MISSISSIPPI.

The Missouri now enters, the great tributary of the basin; and from this point down to the Gulf the river, now called the lower Mississippi, possesses the character of a great river. The combined currents flow in a channel scarcely over a half-mile wide, and make a turbulent stream, especially during high-water periods. The water is muddy, and snags and floating trees, washed from the banks, are more numerous than on the quieter current of the upper Mississippi. The bluffs continue, with a bottom upon one side. From the Missouri, for a distance of about 185 miles, down to Cape Girardeau, the bottoms are almost entirely upon the east side of the river, and are very fertile, including the celebrated American bottom. They are from 3 to 8 miles wide. Many islands occur. Along the bottoms the banks are low, and have to be protected from floods by levees. Scattered through the bottoms are numerous sloughs and crescent-shaped lakes, marking the old courses pursued by the river; cut-offs occur, or the smaller channels are gradually choked with *débris* of fallen trees and snags; sand and mud silt in; and, in time, the old channel is left a slender, curved lake, perhaps several miles away from the river. Below Cape Girardeau, for about 6 miles, the bluffs rise close to the river on each side, and then leave it—on the east passing up the valley of the Ohio, which enters about 30 miles below; on the west disappearing in the Great swamp, caused by the subsidence of the ground in the early part of the present century.

Alluvial region.—At Commerce, where the river passes from the bluffs, may be said to commence the alluvial section of the basin. It continues clear to the Gulf, the land being low, and, indeed, beneath the flood level of the river. The natural surface is highest immediately at the river bank and slopes back for from 1 to 3 miles to the swamps. The soil is of great fertility, and has been largely reclaimed by levees thrown up along the river banks; but these are continually giving way, allowing the river to inundate the country. It was estimated that during the floods of the fall of 1881, when at places the river was higher than it had before been since the flood of 1858, the damage resulting below Saint Louis amounted to $3,300,000. As above the Ohio river, so also in this portion, the banks are constantly changing, and many lakes, sloughs, and swamps are the result. The course of the river is very winding. From the mouth of the Ohio to the Gulf, by the river channel, the distance is 1,097 miles, while in a straight line it is only 497 miles. Sometimes in rounding a great bend, the erosion will take place on both sides of the neck, until finally a channel is worn through and a cut-off is produced. This has occurred in a great many instances, whereby the channel is apparently much shortened and the velocity increased. The bluffs approach the river only at Helena, on the west, but at several places the river runs close under the eastern bluffs, from 200 to 400 feet high. The points of contact below the Ohio river are at Hickman, at the first, second, and third Chickasaw bluffs, and next at Memphis, Tennessee, where is the fourth Chickasaw bluff. Below Memphis is the wide Yazoo bottom, and the next place at which the bluffs strike the river is at Vicksburg, Mississippi. Then the line of bluffs is near to the river down to Baton Rouge, and touches it at nine points between those places. At Baton Rouge the last of the bluffs is seen. They there leave the river's course and veer to the eastward, in the direction of the Gulf coast. The alluvial region has an average width of 30 to 40 miles from the Ohio down to Baton Rouge, and at the Yazoo bottom is not less than 80 miles across.

The Delta.—A few miles below Baton Rouge may be said to commence the delta of the Mississippi. There the highland turns eastward as already described, and strikes the Gulf about 100 miles east. On the west the line of highland runs along the shore-line of the Gulf at an average distance from it of 20 or 30 miles, and marks the limit of the alluvial soil. The features of the alluvial region are the characteristics which distinguish the lower Mississippi: Low shores, with occasionally the appearance of a bluff; great sweeping curves of the river; in the lower part, particularly, swamps and bayous. The growth of cottonwood, willow, sycamore, ash, and elm gradually changes toward the south; the cypress appears in the swamps, and becomes more abundant; sweet-gum and the tupelo are noticed; the palmetto is seen, and Spanish moss festoons the trees. In lower Louisiana the live-oak

is met with. About the mouth of the river the ground and vegetation gradually fades away into the Gulf, as is the case with delta-forming rivers. The climate and the vegetation are semi-tropical. We have thus followed the river from its cold springs in northern Minnesota to where it is lost in the warm waters of the gulf of Mexico.

The bed of the river.—The bed of the river consists of stiff clay, mud, sand, and gravel. Toward the mouth, where even what land there is has been built up by the river itself, the shores and bed are soft, and the land marshy, except where reclaimed; and generally below high-water level. Large quantities of sediment are yearly carried down to the Gulf, and the building out of the delta is constantly going on. The estimate has been made that enough solid matter is carried down to the Gulf each year, either in suspension, or else pushed along the bed of the river, to cover one square mile to the depth of 268 feet. This mud is spread out on the bed of the Gulf for miles; and the shores, if such they can be called, immediately at the mouth, are hardly more than a morass.

The mouth.—The river divides into five radiating arms, called passes, at the mouth, and it is very difficult to maintain even a ship-channel through their uncertain beds. Captain Eads' system of training-walls, and the constant agitation of the beds by dredges, are successful with the Southwest pass. A singular phenomenon is that of the "mud lumps", which will rise suddenly to the water surface like a small volcano, with a salt-water spring at the top. They are not satisfactorily accounted for, some attributing them to artesian action, others to the generation of carburetted-hydrogen gas from buried vegetable matter; but, at all events, they occur in unlooked-for places, and often interfere with navigation.

The bayous.—The delta is intersected by numerous bayous, or water-channels, running irregularly through it, and often connected with each other. Three of these, the Atchafalaya bayou, the bayou La Fourche, and the Plaquemine, are of interest, in connection with the Mississippi. The Atchafalaya starts from the mouth of the Red river, and flows thence to the Gulf, with a length of 133 miles, while by the Mississippi the distance is 326 miles. During floods on the Red river that stream feeds the Atchafalaya chiefly; but high water in the Mississippi pours a great flood down the bayou, and threatens to make it the main stream. In 1839 persons could cross at the head of the Atchafalaya in low water on foot. In 1850 it was 50 feet deep at the head in high water, and 730 feet wide. On December 29, 1873, the discharge was 122,000 cubic feet per second into the Atchafalaya. In 1879 it was 85 feet deep at the head during extreme low-water, and 900 feet wide.

Bayou La Fourche has been closed up. In 1860–'61 it had a maximum discharge at the head of about 11,500 cubic feet per second. Bayou Plaquemine had then a maximum drainage from the Mississippi of 35,000 cubic feet per second. The many bayous intersecting the delta are very valuable for the navigation they allow; and Major C. W. Howell, corps of engineers, U. S. army, who is stationed at New Orleans, is clearing them, the chief obstructions being driftwood and snags. Cotton, sugar, and lumber, chiefly southern pine and live-oak, are the principal shipments.

Gulf tides.—The average spring tides on the Gulf are about 1.7 feet, and their effects are not observable to any great extent upon the Mississippi; but probably delicate measurements would show oscillations due to them as far up as the mouth of the Red river, 316 miles from the mouth. The effects of strong winds, however, are much more prominent, and continue for days at a time. The Gulf level is raised 3 or 4 feet, and by hurricanes has in one instance been raised even 7 feet; and an oscillation of 1.5 foot from this cause has been noticed at Red River Landing.

Dimensions of the river.—The following data concerning the river are inserted to give a general idea of its dimensions; elevations, discharge, etc., will be noticed further on. From the Missouri to the Ohio river the width varies from 2,500 feet to a mile; and in some of the bends where islands occur, this increases to even 3 miles between extreme shores. The average slope in this distanc is nearly 6 inches per mile. From the Ohio to the Arkansas the average width is 4,000 feet; depth, in low water, 49 feet; and low-water slope, for most of the distance, about 0.4 foot per mile. From the Arkansas to the Red river the corresponding figures are 3,600 feet, 56 feet, and the low-water slope, 0.158 foot for the lower half of the distance. From Red river to bayou La Fourche the figures are 2,900 feet, 78 feet, and from 0.034 to 0.025 foot. From bayou La Fourche to the mouth, 2,350 feet, 114 feet; and the slope is first 0.008 foot per mile, then 0.004 foot, then increases to 0.036 foot, and at the mouth is about 0.03 foot per mile. The above figures are gathered from Humphreys and Abbot's report, published in 1861.

The maximum flood-rise above low-water level is as follows: At New Orleans, between 14 and 15 feet; from there it increases until it attains an extent of from 50 to 52 feet at Natchez, Vicksburg, and Cairo. At Saint Louis, where the channel is narrow, the highest rise was about 40 feet above low-water. On the upper Mississippi the maximum flood-rise varies from 10 to 20 and even 30 feet.

NAVIGATION AND RIVER IMPROVEMENT.

The navigation of the Mississippi is a matter of great importance, not only to the immediately adjoining states but to the country at large; and as the river requires constant attention to maintain it in a navigable condition, it gives rise to one of the largest works undertaken by the government. The Mississippi River commission, which includes some of the most prominent engineers of the country, deals with the problem of maintaining and improving the navigation of the entire river. At different places along the river are stationed officers of the engineer corps of the army, constantly employed in benefiting navigation. Their interesting reports are embodied in the annual

reports of the chief of engineers. The upper Mississippi is thus divided: The engineer's office at Saint Paul, Minnesota, has charge of the entire river down to that place. From Saint Paul down to the mouth of the Illinois river the channel is in charge of the office at Rock Island, Illinois, with the exception of the Des Moines rapids at Keokuk, which are in charge of a separate office at that place. From the Illinois to the Missouri river the upper Mississippi is under the charge of United States engineers stationed at Saint Louis.

The main features of the work upon the river from the mouth up are the maintaining of a navigable and certain channel (rendered more or less difficult by the mobile character of the bed and banks), and the removal of snags, driftwood, etc. The preservation of a channel at the mouth has been very difficult, and stirring of the soft bed, dredging, the building of training-walls, the closing of most of the passes, and a ship-canal have all been proposed. As has already been mentioned, the combination of the methods of training-walls and stirring the bottom, the outgoing current carrying off the mud, is successful upon the Southwest pass. Upon the river above, dredging is done where necessary; wing-walls are built of brush and gravel to direct or confine the current, and dams are thrown across the heads of sloughs (the minor channels around islands) to concentrate the low-water flow in the main channel. This is necessary, not only on the lower but also on the upper Mississippi, where, although the wearing of the banks is not so great, the bed is largely composed of shifting sand-bars, difficult to control. Above the mouth of the Chippewa river in Wisconsin the difficulty from sand is not so great. In past years navigation was dangerous from the snags and "sawyers" which abounded, especially below the Missouri; now the government boats are careful to remove these, and they are no longer sources of danger. By the caving of banks trees are thrown into the current; finally they sink or become lodged in a bar; a branch rises above the water, or within only a few feet of the surface; this limb is called a "snag". It may be that a tree will float down-stream until its loaded roots sink to the bottom, where they lodge, while the broken end will float, swaying with the current; such an anchored log is called a "sawyer"; a boat passing down stream will run over this, merely depressing it, but when going against the current, the stiff trunk, braced against the bed, may break a hole in the bow.

In the upper portion of the upper Mississippi the low-water navigation is especially difficult. Saint Paul is considered its limit; and Saint Anthony falls, of course, oppose a barrier, only to be surmounted by a canal and locks. Above the falls it is practicable to make the river navigable for small vessels even to Pokegama falls, by dredging, slack-water dams and locks, and the methods usually pursued with the smaller streams.

THE "RESERVOIR SYSTEM".

A scheme for regulating the flow of the upper Mississippi and thus improving the low-water navigation, which has received much attention of late, is the reservoir system. A glance at the map will show that about the upper waters of the main river, the Saint Croix, Chippewa, and Wisconsin rivers, are a great number of lakes and extensive marshes. These, and the generally level surface of the entire basin of the upper Mississippi, make its flow rather more uniform than that of the other streams; but the aim is to increase this beneficial influence upon the river by an extensive system of artificial reservoirs upon the streams mentioned. The reservoir system has not yet been definitely decided upon, but for several years past Major Charles J. Allen, captain of engineers, in charge of the United States engineer's office at Saint Paul, has been making observations and surveys upon which to base calculations of the probable effects of the proposed plan upon the navigation of the river. The topography is so favorable that many extensive reservoirs can be practically constructed. There were, when Major Allen's report of December 12, 1880, was made, seven available sites that had been examined on the Mississippi and its tributaries above Saint Anthony falls, fourteen upon the Saint Croix, twelve on the Chippewa, and six upon the Wisconsin. The entire cost of the proposed improvements was estimated at $1,500,000.

By careful estimates it is found to be practicable to increase the discharge of the several streams mentioned by the following amounts, for a period of ninety days, if the above reservoir sites are improved. The natural low-water discharges at the mouth are also given. The figures are taken from the engineer's reports:

River.	Natural low-water discharge per second.	Extra supply per second from reservoirs during ninety days.
	Cubic feet.	*Cubic feet.*
Upper Mississippi at Saint Paul	5,800	7,100
Saint Croix	2,800	4,400
Chippewa	2,600	2,800
Wisconsin	4,700	2,300

The calculations are made with liberal allowances for loss from evaporation, etc., and no reason appears why, with the above additions to the low-water flow, the tributaries, at least, shall not be very greatly benefited. How would it be with the main stream? From Major Allen's report to the chief of engineers, dated December 12, 1879, the following figures are obtained: For 100 days a discharge of 12,200 cubic feet per second could be depended

upon at Saint Paul, during the low water of summer and fall. The discharge during the very low stage is now 5,800 cubic feet. Below the mouth of the Saint Croix the discharge for 100 days of low water would be about 18,000 cubic feet per second, while the discharge during the very low stage is now about 8,600 cubic feet. Below the Chippewa river the discharge for 100 days of low water would be, in round numbers, 24,000 cubic feet per second, while the extreme low-water flow is now 11,000 cubic feet. Below the Wisconsin the discharge for 100 days of low water would be about 36,000 cubic feet per second, while the extreme low-water discharge is now 17,000 cubic feet.

Thus the low-water discharge would be more than doubled and navigation greatly benefited. That the effects would be felt for a great distance down the river can hardly be doubted. The adding of 16,600 cubic feet per second during three months of the year to the low-water volume is not to be disregarded: 16,600 cubic feet per second is 87 per cent. of the extreme low-water flow at Rock Island, 55 per cent. of that above the mouth of the Illinois river, and about 30 per cent. of that at Saint Louis, below the mouth of the Missouri.

The adoption of the reservoir system would also be of very great value to the water-power interests along the river, but that will be considered later.

GEOLOGY OF THE MISSISSIPPI BASIN.

In the "General Remarks" prefacing the Report of the Water-power of the Northwest, allusion was made to the base, or rib of Archæan rock, extending west through Canada and the northern part of the United States into Minnesota, upon which, as a shore, the successive strata were deposited toward the south. The Paleozoic seas, breaking at the base of this line of Archæan mountains, deposited their sediments, as they advanced and receded, in strata of successive outcrop, with a general slope south and west in the central portion of the modern continent.

Then came the Glacial period, covering everything in the north with a blanket of drift, and, with the subsequent modifications, changing the entire topographical character of that region.

These are only the prominent facts which stand out in the geological history of the Mississippi basin; there were many minor changes of great influence in determining our country as we see it.

The Mississippi in its course southward crosses all the successive strata just mentioned. The sources are underlaid, after the covering of drift is removed, directly by the Archæan rock; the mouth is surrounded by the soft marshes of its own delta now forming; between these two extremes all ages are represented.

Modern action of the river.—At the close of the Quaternary age the Mississippi was striving to clear from its bed the accumulation of the Drift period, a process still in progress. This is a slow operation, with its comparatively small volume and diminished slope. Its bed is yet 100 feet above the rocky bottom of the ancient trough, nearly as far north as the junction of the Minnesota river, and at the mouth several hundred feet of transported drift material lie between. In only two places below the mouth of the Minnesota does the river run over a rock bed, viz., at the Rock Island and at the Des Moines rapids. It was suggested by Dr. J. S. Newberry, and subsequently ascertained by General G. K. Warren, of the corps of engineers, U. S. army, that in these two cases the river had forsaken its ancient channel and was running across the country, wearing a new passage in the rock.

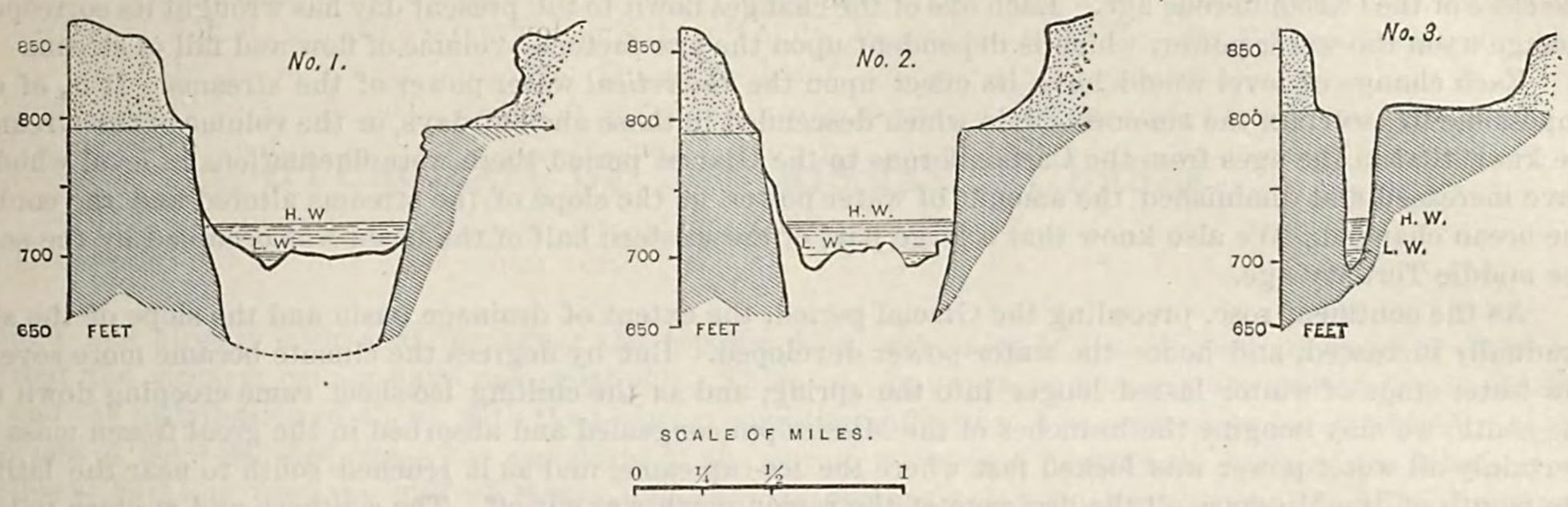
Significance of the modern features.—We can now see the true significance of the present physical aspect of the Mississippi river. The rocky bluffs that limit the trough of the upper river are the old cliffs which confined the ancient stream. The finely-divided soil which crowns their summits, and in many places rounds their outlines, is the *Bluff* formation, the Loess, which has been washed out of the trough by the modern river. The prairies and bottoms which skirt the river between the bluffs are built out of the modified drift and Loess with which the ancient trough was filled, covered in places with the alluvium of the modern river. The bluffs of stratified clay, gravel, sand, etc., along the lower river have been carved out of the ancient deposits brought down to the sea by the river itself. Lastly, the delta is the modern representative of that ancient process which gradually filled the lower trough of the river, except that the latter was the filling up of an arm of the sea, while the modern creation is a true delta formation, throwing its arms far out into the gulf of Mexico. During past ages the mouth of the Mississippi has passed north and south several times, and more than twice has it visited every point along a line of 1,000 miles.

There are a few points to be noted in the geological history of the *headwaters* of the Mississippi.

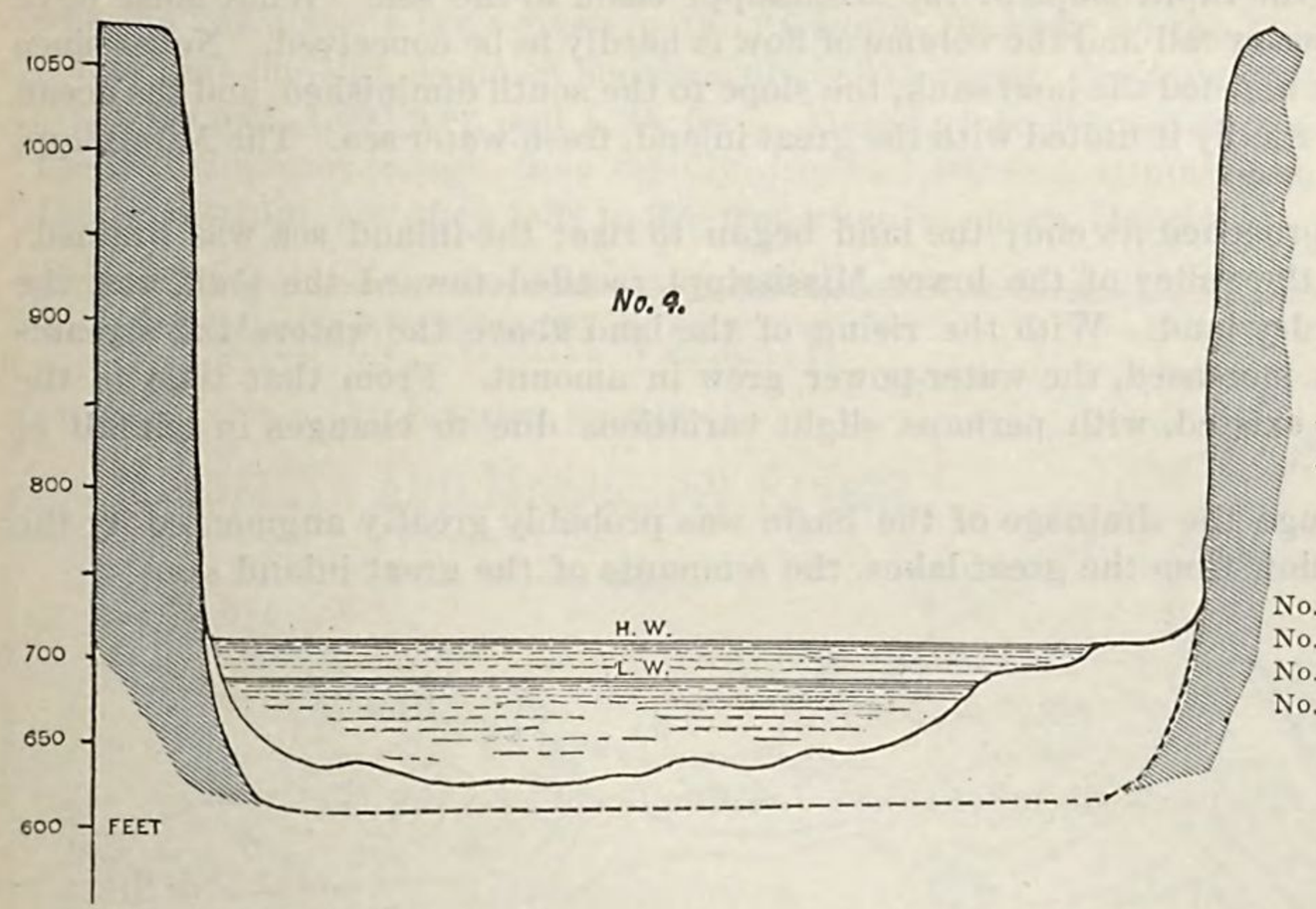
Ancient course of the upper Mississippi.—During and subsequent to the Glacial period the representatives of lake Michigan and lake Erie overflowed into the Mississippi from the east, and to the north the vast drainage basin of lake Winnipeg, in British America, added its tribute to the Mississippi. In the report on the Red river of the North, attention has been called to the evidence in favor of the theory that the Minnesota valley was once the channel whereby the large drainage of the lake Winnipeg region passed south to the Mississippi. Now, the real continuation of the old Mississippi trough above Saint Paul is this valley of the Minnesota, as the accompanying sections and map show, and the truth seems to be that in days before lake Winnipeg changed its allegiance the Minnesota river was the true upper Mississippi, and the modern stream which bears that name, although probably much larger than now, was a comparatively insignificant tributary from the area to the eastward, entering the great river at some point of the Minnesota valley a few miles above the present junction.

Saint Anthony falls.—In the case of the Mississippi river above the junction of the Minnesota we find a condition similar to that existing at the Rock Island and the Des Moines rapids. The river has deserted its ancient bed a

short distance above Saint Anthony falls, and is now excavating a new channel through the rock. The peculiar character of the strata there—Trenton limestone underlaid by the soft Saint Peter's sandstone—has made the falls possible. Hence Saint Anthony falls are recent.



Vertical scales show heights above sea-level.



SECTIONS
OF THE
MISSISSIPPI AND MINNESOTA VALLEYS,
Copied from Geological Report of Minnesota, 1880.

No. 1, Section of Minnesota valley above mouth.
No. 2, Section of Mississippi valley below mouth of Minnesota river.
No. 3, Section of Mississippi valley above mouth of Minnesota river.
No. 4, Section of Mississippi valley at lake Pepin.

One point to be noticed is, that in approaching the sources of the river we have been leaving behind us one outcrop after another of the different layers of rock, and are nearing the primitive metamorphic rock of the Archæan base of the continent. It is true that the rock is usually covered, except where the rivers run, by the blanket of drift, but the evidence is plain that we are nearing the northern coast-line of the old Paleozoic sea. Ascending the Minnesota valley, the bed after a time runs out upon the hard granites and syenites of the primitive formation, and on the upper Mississippi a trip of 78 miles above Saint Anthony falls brings us to rapids where the water dashes over the unyielding Archæan rock. Because of the resisting nature of these earliest formations the ancient streams carved out their channels slowly, and hence no deep troughs are to be seen, such as mark their passage through the softer sedimentary rock lying farther south; the only bluffs of any prominence due to erosion consist of drift. Thus the troughs of the Minnesota and of the extreme upper Mississippi have been worn through the drift blanket, in many places to the hard granitic bed; the bluffs are composed of drift entirely, but as the sources are neared, where the river has made comparatively little impression even upon the soft material of the drift, the bluffs sink into low banks, and the bed is entirely in clay, sand, and gravel, while accumulations of bowlders form the only rapids.

Effect of the metamorphic rock upon the water-power.—The presence of the primitive rock in this region of the Mississippi basin has a most important bearing upon the water-power of this portion of the northwest, as the resistance to erosion preserves the falls and rapids, whereas in a more uniform and softer material the descent would have been distributed along the entire course of the river.

Sketch of the probable past history of the water-power.—There is no evidence that the Mississippi existed previous to the close of the Carboniferous age. Each one of the changes down to the present day has wrought its corresponding change upon the water-power, which is dependent upon the two factors—volume of flow and fall of stream.

Each change of level would have its effect upon the *theoretical* water-power of the streams. It is, of course, impossible to ascertain the amount of rain which descended in those ancient days, or the volume of the streams, but we know that in the ages from the Carboniferous to the Glacial period there were fluctuations in level which must have increased and diminished the amount of water-power, as the slope of the streams altered and the confines of the ocean changed. We also know that a large part of the western half of the basin was occupied by the sea until the middle Tertiary age.

As the continent rose, preceding the Glacial period, the extent of drainage basin and the slope of the streams gradually increased, and hence the water-power developed. But by degrees the climate became more severe, the low-water stage of winter lasted longer into the spring, and as the chilling ice-sheet came creeping down toward the south, we may imagine the branches of the Mississippi congealed and absorbed in the great frozen mass above. Certainly all water-power was locked fast where the ice-cap came, and as it reached south to near the latitude of the mouth of the Missouri, all the drainage of the region north was cut off. The southern and western tributaries of the Missouri and the southern part of the Ohio basin were free, and as the lower rim of the ice-cap was constantly melting, this tribute swelled the streams to large size. The water-power must then have been confined to that portion of the basin not covered by the ice. As the ice-sheet receded, the volume of water from its melting increased.

When it had retreated into northern Minnesota, the northern part of the continent was elevated many hundred feet above its present level, and for hundreds of miles east and west the great barrier of the retreating glacier was pouring its floods of water and mud down the rapid slope of the Mississippi basin to the sea. What must have been the power of these torrents, with the heavy fall and the volume of flow is hardly to be conceived. Never since has it been approached; for after the glacier receded the land sank, the slope to the south diminished, and the ocean ascended the valley of the Mississippi, until finally it united with the great inland, fresh-water sea. The Mississippi as a river was gone.

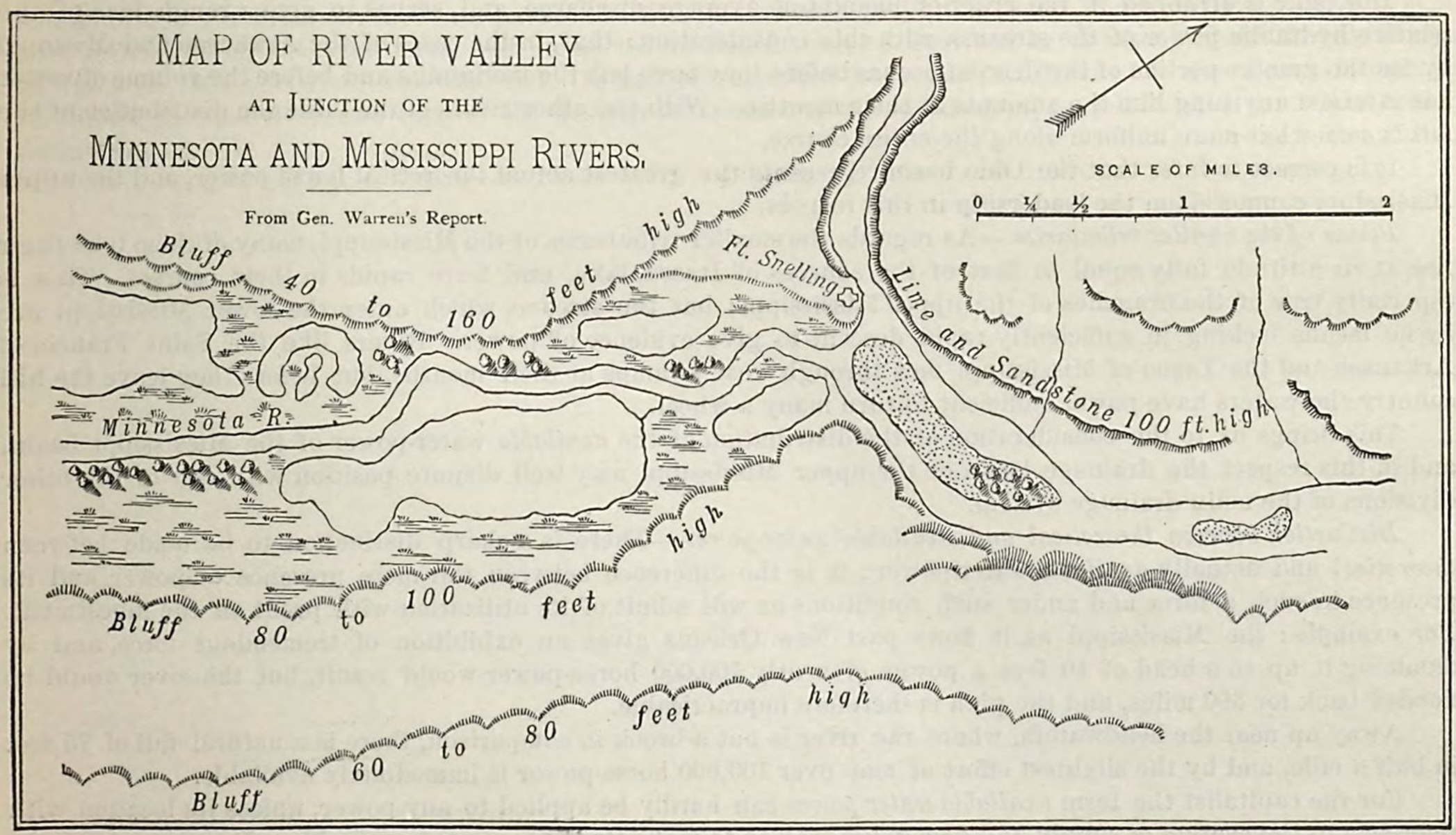
Finally, the period of submergence approached its end; the land began to rise; the inland sea was drained; the arm of the ocean which had occupied the valley of the lower Mississippi receded toward the Gulf, and the basin of the Mississippi became once more dry land. With the rising of the land above the waters the streams reappeared, and as the slope of their beds increased, the water-power grew in amount. From that time to the present the same condition of affairs has existed, with perhaps slight variations due to changes in rainfall or elevation of the land.

During the early part of the modern age the drainage of the basin was probably greatly augmented by the discharge from lake Winnipeg and by overflow from the great lakes, the remnants of the great inland sea.

HYDROLOGY OF THE MISSISSIPPI BASIN.

Enough has already been said regarding the topographical character of the Mississippi basin to make it evident that the streams cannot have any great fall. There are, however, numerous water-powers, moderate in extent; and the distribution of these, with the physical conditions affecting them, now claim our attention.

Elevation of the water-shed line.—The elevations of the line of water-shed limiting the basin of the Mississippi are as follows: Starting from the gulf of Mexico and running northeast, it soon rises, among the hills of central Mississippi, to a height of 500 and 700 feet; bending eastward across northern Alabama its elevation is from 1,100 to 1,160 feet. Then it strikes the Appalachian system of mountains, and, gradually rising, crosses western North Carolina at an elevation varying from 2,200 to 5,000 feet. Through Virginia and West Virginia the crest-line sinks to an altitude of 2,500 or 3,000 feet, and then, in crossing Pennsylvania, to 2,000 to 2,500 feet. In Ohio the height is 1,200 feet, falling to 700 feet. Passing around the southern end of lake Michigan at an elevation, near Chicago, of 610 feet, the boundary line rises in passing north into Wisconsin. The course through the latter state and Minnesota has already been given in the "General Remarks on the Water-power of the Northwest". Suffice it to say here that the line assumes successively in Wisconsin the following typical levels: 980 feet, 910 (at Portage City), 1,530 feet, 1,600 feet, and 1,200 feet. Passing into Minnesota, it dips to 650 feet in crossing the western end of the lake Superior trough, then rapidly rises to 1,400 feet, attaining an elevation of about 1,680 feet at the source of the Mississippi, and then falls to 995 feet where it enters Dakota.



Through Dakota it extends in a northwest direction, rising from 1,000 to 2,000 feet, and attaining a greater altitude in British America. When it re-enters the United States in Montana we find it at an elevation of 6,000 or 7,000 feet above the sea; it has entered the Rocky mountains, and from there through Wyoming and Colorado the elevation ranges from 6,000 to 14,000 feet. In crossing the Llano Estacado in New Mexico the line of water-

shed falls to an elevation of about 4,500 feet, then descends in Texas, crosses Louisiana at an altitude of from 200 to 300 feet, and finally drops once more to the waters of the Gulf. The hypsometric map prepared by Mr. Henry Gannett, and published in Volume I (Population) of the quarto series of the Tenth Census reports, illustrates the elevations of the Mississippi basin.

It will be noticed from the preceding figures that the highest elevations are attained on the west and east, 14,000 and 5,000 feet, respectively. On the north the line is comparatively low, probably not exceeding 1,700 or 1,800 feet in height, except in western Dakota and Montana, and in this low region are the sources of the upper Mississippi. Where the line passes the western end of lake Superior, not more than 130 miles from the extreme headwaters, the elevation above the sea is less than in the state of Mississippi.

Comparison of the large streams.—To use a homely illustration, the surface of the Mississippi basin may be compared to the wide brim of a soft hat, with the sides rolled up where the eastern and western mountain chains are, and the front and back low. Through the center, from front to rear, runs the main stream, with a comparatively gentle slope; from the high, upturned edges on the west and east come the large tributaries with rapid fall, especially at their headwaters, while between them are the smaller branches of the main river, moderate in their descent, and in this respect resembling the Mississippi itself.

Hence, we would not look to the main stream above the junction of the large tributaries for the greatest exhibition of water-power (using the term in a strictly theoretical sense). Its total fall from source to mouth is only 1,680 feet, which is much exceeded by most of the large streams.

The following table shows the entire descent from source to mouth of the main rivers of the basin:

River.	Average flow per second.	Length.	Fall.	Slope per mile.
	Cubic feet.	*Miles.*	*Feet.*	*Feet.*
Ohio	203,800	1,204	1,390	1.15
Missouri	121,900	2,908	(?)6,400	2.20
Upper Mississippi	118,600	1,265	1,287	1.02
Arkansas	63,000	1,514	9,900	6.55
Red	50,000	1,200	2,240	1.87

The table is arranged in the order of amount of average discharge, and serves to give a rough idea of the relative hydraulic power of the streams, with this consideration: that, in the cases of the Arkansas and Missouri by far the greater portion of the descent occurs before they have left the mountains and before the volume of water has attained anything like the amounts at their mouths. With the other rivers of the table the distribution of the fall is somewhat more uniform along the entire course.

It is correct to infer that the Ohio basin represents the greatest actual theoretical horse-power, and the upper Mississippi cannot claim the leadership in this respect.

Power of the smaller tributaries.—As regards the smaller tributaries of the Mississippi, many of them take their rise at an altitude fully equal to that of the sources of Itasca lake, and have rapids in their courses. This is especially true of the branches of the upper Mississippi; but the streams which enter the lower Mississippi are by no means lacking in sufficiently rapid descent to give evidence of power. Rivers like the Saint Francis of Arkansas and the Yazoo of Mississippi flow through vast swamps at their mouths, but before they leave the hill country the waters have power sufficient to turn many a wheel.

This brings us to the consideration of the distribution of the *available* water-power of the Mississippi basin, and in this respect the drainage basin of the upper Mississippi may well dispute position with any of the other divisions of the main drainage system.

Distinction between theoretical and available water-power.—There is a sharp distinction to be made between *theoretical* and actually *available* water-power; it is the difference between the mere presence of power and its presence in such a form and under such conditions as will admit of its utilization with profit on the investment. For example: the Mississippi as it flows past New Orleans gives an exhibition of tremendous force, and by damming it up to a head of 10 feet a power of nearly 700,000 horse-power would result, but the river would be flooded back for 300 miles, and the plan is therefore impracticable.

Away up near the headwaters, where the river is but a brook in comparison, there is a natural fall of 75 feet in half a mile, and by the slightest effort of man over 100,000 horse-power is immediately available.

For the capitalist the term *available water-power* can hardly be applied to any power, unless its location with reference to the centers of supply and demand is such as to make its improvement profitable. It appears to be the province of the capitalist to decide whether a power can be made to pay after improvement, and of the engineer to decide whether it can be improved within a certain limit of expense, and to do it. Both classes sometimes do double duty, often at a loss in the case of those who understand the management of finances better than engineering.

In this report the adjective *available* is applied to those water-powers concerning which there is no physical obstacle to development with what, in ordinary cases, would be a reasonable expense, and the consideration of whether a woolen mill can be made to pay in one place or whether a cotton factory is profitable in another is left to others. It is hoped, however, that sufficient is said in the general descriptions of the various regions regarding the nature of the country, crops, facilities of transportation, etc., to convey some general ideas upon the financial aspects of the subject.

Centers of available power.—Having given the above definition of *available water-power*, we reiterate the statement that, as regards *available* power, the upper Mississippi basin may well dispute position with any of the other divisions of the main drainage system; and for this reason, mainly: the available power of the side-streams is, as a rule, greater than that of the branches of the Missouri at least, while on the main stream itself exist available powers of large dimensions. On the Ohio, at Louisville, is a large power, and when the scheme of slack-water navigation is carried out, it is possible that others will be available, but two of its largest tributaries enter very near its mouth, below all available power, and back-water is a very serious drawback to improvement. On the Missouri there is no available power until away up toward the mountains of the west, where the stream is small and the country sparsely settled; and the Arkansas and Red rivers offer no powers on a grand scale.

All these are eclipsed by the famous power at Saint Anthony falls, and the Rock Island and the Des Moines rapids, by a heavy outlay, can be made to yield water-powers of large size. These are all upon the upper Mississippi, and the last two are the only available powers on the river below Saint Anthony falls. Above Minneapolis, on the upper Mississippi, are several rapids where from 5,000 to 10,000 theoretical horse-power is available, while a number of the tributaries present powers of equal magnitude.

In considering the large tributaries, the fact must not be lost sight of that there is a widespread distribution of available powers of moderate size throughout this central drainage system of the continent, and of great value are they to the country. Alike, among the sandy hills of Mississippi and Louisiana, on the wide prairies of the West, and among the mountains, are many powers, some of which already yield rich returns to industry. The greatest utilization of the power is on the upper Mississippi and its tributaries and the northern branches of the Ohio river, but other water-powers are fast coming into use, as the country to the westward is settled.

Centers of power employed.—The chief centers of actual use of power, exclusive of the Ohio basin, which has not been visited at the writing of this report, are Saint Anthony falls, in Minnesota, on the upper Mississippi, and the region lying in Illinois, southwest of Chicago, within a distance of 50 or 60 miles of that place. There are no large manufacturing centers using water-power elsewhere, either because it does not exist or because there is no demand for it if it does. In the lower part of the Missouri basin there is a fine power, though of comparatively small size, at Sioux falls, which has lately been improved to some extent, as described in the report of Mr. Dwight Porter, to whom the Missouri river was assigned. It may be remarked here that Mr. Porter has also reported upon the Arkansas, the Red river, and most of the western tributaries of the Mississippi, as well as upon the Ohio and its tributaries.

Table giving the elevation, drainage area, rain-fall, flow,

Station.	Number of station.	Distance below preceding station.	Distance below source of the river.	Elevation of ordinary low water above the sea-level.	Fall from preceding station.	Average slope, per mile, to preceding station.	Average slope, per mile, to source of river.	Drainage area above station.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Square miles.*
Utmost source of the Mississippi	1	.....	.....	1,680.00	.....	.....	.....	.....
Head of lake Itasca	2	6.00	6.00	1,575.00	105.00	17.500	17.500	.....
Outlet of lake Itasca	3	4.00	10.00	1,575.00	0.00	0.000	10.500	78±
Above mouth of the Pinniddiwin	4	24.00	34.00	1,375.00	200.00	8.308	8.941	233
Mouth of Pinniddiwin river	5	0.00	34.00	1,375.00	0.00	0.000	8.941	384
Mouth of east branch of the Mississippi	6	19.00	53.00	1,356.00	19.00	1.000	6.113	543
Head of lake Bemidji	7	2.5	55.5	1,353.46	2.54	1.016	5.883	543
Outlet of lake Bemidji	8	2.5	58.00	1,353.46	0.00	0.000	5.630	583
Head of Cass lake	9	17.00	75.00	1,299.46	54.00	3.176	5.074	694
Mouth of Turtle river and outlet of Cass lake	10	7.5	82.5	1,299.46	0.00	0.000	4.615	1,073
Head of lake Winnibigoshish	11	20.00	102.5	1,289.36	10.10	0.505	3.815	1,114
Outlet of lake Winnibigoshish	12	13.00	115.5	1,289.36	0.00	0.000	3.382	1,406
Mouth of Leech Lake river	13	23.5	139.00	1,278.56	10.80	0.459	2.888	2,554
White Oak point	14	16.5	155.5	1,274.96	3.60	0.218	2.605	2,719
Head of Pokegama falls	15	30.00	185.5	1,266.06	8.90	0.297	2.231	2,952
Foot of Pokegama falls	16	0.1	185.6	1,251.96	14.10	141.000	2.306	2,952
Head of Grand rapids	17	3.5	189.1	1,249.06	2.90	0.829	2.273	2,966
Foot of Grand rapids	18	0.3	189.4	1,244.06	5.00	16.667	2.249	2,966
Mouth of Prairie river	19	2.5	191.9	1,242.96	1.10	0.439	2.241	3,457
Bend in the river to the southeast	20	20.00	212.00	1,234.19	8.77	0.439	2.103	3,554
Mouth of Swan river	21	19.00	230.9	1,225.85	8.34	0.439	1.534	3,928
Mouth of Sandy Lake outlet	22	41.00	271.9	1,207.86	17.99	0.439	1.762	4,457
Mouth of the Willow and White Elk rivers	23	30.00	301.9	1,198.20	9.66	0.322	1.596	5,049
Mouth of Rice river	24	17.00	318.9	1,192.72	5.48	0.322	1.528	5,359
Mouth of Pine river	25	37.00	355.9	1,171.31	21.41	0.579	1.120	6,705
Brainerd	26	22.00	377.9	1,151.76	19.55	0.934	1.398	6,967
Mouth of Crow Wing river	27	10.00	387.9	1,145.06	6.70	0.670	1.121	10,573
Head of Little falls	28	21.00	408.9	1,089.86	55.20	2.629	1.444	11,084
Foot of Little falls	29	0.4	409.3	1,082.56	7.30	18.250	1.460	11,084
Watab	30	24.6	433.9	1,000.16	82.40	2.350	1.567	12,120
Head of Sauk rapids and mouth of Sauk river	31	6.00	439.9	987.66	12.50	2.083	1.347	13,242
Foot of Sauk rapids	32	0.8	440.7	976.36	11.30	14.125	1.597	13,242
Saint Augusta	33	8.3	449.00	945.86	30.50	3.675	1.635	13,327
Clearwater	34	8.8	457.8	935.36	10.50	1.193	1.627	13,582
Monticello	35	14.3	472.1	890.26	45.10	3.154	1.673	13,688
Mouth of Elk river	36	12.00	484.1	850.26	40.00	3.333	1.716	14,360
Mouth of Crow river	37	5.00	489.1	841.06	9.20	1.840	1.715	17,457
Mouth of Rum river	38	8.2	497.3	825.96	15.10	1.846	1.717	19,016
Minneapolis, at Saint Anthony falls	39	17.3	514.6	793.36	32.60	1.890	1.723	19,585
Mouth of Minnesota river	40	9.00	523.6	683.52	109.84	12.900	1.521	35,819
Saint Paul bridge	41	4.00	527.6	681.36	2.16	0.540	1.893	35,824
Mouth of Saint Croix river	42	29.00	556.6	666.49	14.87	0.513	1.821	43,872
Mouth of Cannon river	43	21.25	577.85	661.41	5.08	0.238	1.763	45,646
Mouth of Chippewa river	44	33.00	610.85	659.56	1.85	0.056	1.670	55,876
Mouth of Zumbro river	45	7.00	617.85	655.87	3.69	0.527	1.658	57,222
Mouth of Buffalo river	46	4.75	622.6	653.04	2.83	0.596	1.641	57,690
Fountain City	47	22.25	644.85	640.67	12.37	0.556	1.596	58,491
Mouth of Trempealeau river	48	13.25	658.1	633.29	7.38	0.556	1.590	59,256
Trempealeau	49	7.00	665.1	630.36	2.93	0.419	1.578	59,335
Mouth of Black river	50	17.5	682.6	624.77	5.59	0.319	1.547	61,659
Mouth of Root river	51	4.00	686.6	622.81	1.96	0.490	1.540	63,900
Mouth of upper Iowa river	52	29.5	716.1	611.51	11.30	0.383	1.492	65,484
Lynxville	53	22.75	738.85	605.02	6.49	0.285	1.455	65,844
Mouth of Wisconsin river	54	18.77	757.62	600.11	4.91	0.262	1.425	78,565
Mouth of Turkey river	55	21.71	779.33	593.30	6.81	0.314	1.393	80,467
Dubuque	56	32.78	812.11	581.48	11.82	0.361	1.353	81,322
Mouth of Fever river	57	5.98	828.09	579.59	1.89	0.316	1.329	81,689
Mouth of Maquoketa river	58	12.67	840.76	572.36	4.17	0.329	1.318	83,772
Fulton	59	32.95	873.71	563.00	9.36	0.284	1.278	84,857
Mouth of Wapsipinicon river	60	15.62	889.33	558.25	4.75	0.304	1.261	87,558

power, etc., for various points on the Mississippi river.

Average annual precipitation above station.	Average annual precipitation, per second, on area above station.	Flow, per second, past station.		Flow, per second, past station, per square mile of drainage area.		Ratio of average flow to average precipitation above station.	Ratio of ordinary low flow to average flow.	Theoretical horse-power at station, under an assumed head of 10 feet.		Number of station.
		Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.			Ordinary low flow.	Average flow.	
Inches.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Per cent.*		*Horse-power.*	*Horse-power.*	
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2
.....	144	26	56	0.33	0.716	38.8	0.464	29	64	3
25.00	429	77	167	0.33	0.716	38.9	0.461	87	189	4
25.00	707	127	275	0.33	0.716	38.8	0.462	144	312	5
25.00	1,000	180	389	0.331	0.716	38.9	0.463	204	441	6
.....	1,000	180	389	0.331	0.716	38.9	0.463	204	441	7
.....	1,076	194	418	0.333	0.717	38.8	0.464	220	474	8
.....	1,280	232	496	0.334	0.715	38.7	0.468	263	563	9
25.00	1,979	361	783	0.336	0.729	39.5	0.468	410	898	10
.....	2,048	374	809	0.336	0.726	39.0	0.462	424	918	11
.....	2,589	474	1,015	0.337	0.722	39.2	0.467	538	1,152	12
25.00	4,707	896	1,903	0.351	0.746	40.4	0.471	1,017	2,159	13
.....	5,011	952	2,019	0.351	0.743	40.2	0.472	1,080	2,291	14
.....	5,443	1,031	2,183	0.343	0.739	40.1	0.472	1,170	2,477	15
.....	5,443	1,031	2,183	0.349	0.739	40.1	0.472	1,170	2,477	16
.....	5,466	1,036	2,192	0.349	0.739	40.1	0.473	1,175	2,487	17
.....	5,466	1,036	2,192	0.349	0.739	40.1	0.473	1,175	2,487	18
25.00	6,370	1,183	2,572	0.342	0.744	40.3	0.460	1,342	2,918	19
.....	6,555	1,216	2,642	0.342	0.743	40.3	0.460	1,380	2,997	20
25.06	7,257	1,330	2,935	0.338	0.747	40.4	0.453	1,509	3,330	21
25.11	8,251	1,498	3,344	0.336	0.748	40.4	0.448	1,699	3,794	22
25.16	9,364	1,672	3,787	0.331	0.750	40.4	0.442	1,897	4,296	23
25.18	9,946	1,766	4,019	0.329	0.750	40.4	0.439	2,004	4,560	24
25.21	12,456	2,167	4,953	0.323	0.739	39.7	0.438	2,458	5,619	25
.....	12,948	2,246	5,101	0.323	0.732	39.4	0.440	2,548	5,787	26
25.30	19,723	3,328	7,602	0.315	0.719	38.5	0.438	3,776	8,624	27
.....	20,713	3,483	7,899	0.314	0.713	38.1	0.441	3,951	8,969	28
.....	20,713	3,483	7,899	0.314	0.713	38.1	0.441	3,951	5,969	29
.....	22,686	3,793	8,493	0.313	0.701	37.4	0.447	4,303	9,635	30
25.45	24,834	4,123	9,174	0.312	0.693	36.9	0.449	4,678	10,408	31
.....	28,434	4,123	9,174	0.312	0.694	36.9	0.449	4,678	10,408	32
.....	24,997	4,152	9,223	0.312	0.692	36.8	0.450	4,710	10,463	33
.....	25,484	4,239	9,369	0.312	0.690	36.7	0.452	4,809	10,629	34
.....	25,687	4,275	9,430	0.312	0.689	36.7	0.453	4,850	10,698	35
25.49	26,974	4,462	9,816	0.311	0.684	36.3	0.456	5,062	11,136	36
26.02	33,577	5,391	11,924	0.309	0.683	35.5	0.452	6,116	13,528	37
26.18	36,682	5,859	12,855	0.308	0.676	35.3	0.456	6,647	14,584	38
.....	37,933	6,017	13,193	0.307	0.674	34.7	0.457	6,826	14,967	39
27.07	71,456	8,576	20,922	0.239	0.584	29.2	0.410	9,729	23,736	40
.....	71,467	8,577	20,925	0.239	0.584	29.2	0.410	9,731	23,738	41
27.63	89,324	11,500	27,398	0.262	0.624	30.6	0.420	13,047	31,083	42
27.70	93,160	12,006	28,453	0.263	0.623	30.5	0.422	13,621	33,380	43
28.10	118,687	15,719	37,712	0.281	0.674	31.7	0.417	17,833	42,784	44
28.83	121,563	16,096	38,460	0.281	0.672	31.6	0.419	18,261	43,633	45
28.86	122,701	16,227	38,756	0.281	0.672	31.5	0.419	18,410	43,969	46
.....	124,807	16,435	39,283	0.281	0.671	31.4	0.418	18,646	44,567	47
28.99	126,571	16,648	39,766	0.276	0.671	31.4	0.419	18,887	45,155	48
.....	126,768	16,669	39,815	0.281	0.671	31.4	0.419	18,911	45,170	49
29.18	132,590	17,433	41,840	0.283	0.679	31.5	0.417	19,778	47,467	50
29.25	137,729	18,064	43,162	0.283	0.675	31.3	0.419	20,494	48,967	51
29.38	141,737	18,705	44,186	0.286	0.675	31.1	0.423	21,228	50,129	52
.....	142,666	18,799	44,418	0.286	0.675	31.1	0.423	21,327	50,392	53
30.31	175,465	23,704	56,101	0.314	0.742	31.9	0.423	26,892	63,647	54
30.35	179,988	24,233	57,272	0.301	0.711	31.8	0.423	27,492	64,975	55
.....	182,281	24,455	57,845	0.301	0.711	31.6	0.423	27,744	65,625	56
30.45	183,264	24,550	58,091	0.301	0.711	31.6	0.423	27,852	65,904	57
30.58	188,789	25,111	29,518	0.312	0.710	31.5	0.422	28,488	67,523	58
.....	191,746	25,393	60,228	0.299	0.710	31.4	0.422	28,808	68,329	59
30.85	199,109	26,095	62,139	0.298	0.711	31.2	0.420	29,604	70,497	60

Table giving the elevation, drainage area, rain-fall, flow, power,

Station.	Number of station.	Distance below preceding station.	Distance below source of the river.	Elevation of ordinary low water above the sea-level.	Fall from preceding station.	Average slope, per mile, to preceding station.	Average slope, per mile, to source of river.	Drainage area above station.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Square miles.*
Head of Rock Island rapids, at Le Claire	61	7.13	896.46	557.43	0.82	0.115	1.252	87,703
Foot of Rock Island rapids, at Rock island	62	14.75	911.21	537.03	20.40	1.383	1.254	87,842
Mouth of Rock river	63	2.12	913.33	536.37	0.66	0.311	1.252	98,821
Muscatine	64	29.89	943.22	526.86	9.51	0.318	1.223	99,100
Mouth of Iowa river	65	20.50	963.72	521.22	5.64	0.275	1.202	111,845
Mouth of Henderson river	66	25.12	988.84	510.86	10.36	0.412	1.183	113,276
Burlington	67	6.40	995.24	508.36	2.50	0.391	1.177	113,495
Mouth of Skunk river	68	4.09	999.33	506.58	1.78	0.435	1.174	118,141
Head of Des Moines rapids, at Montrose	69	25.98	1,025.31	497.76	8.82	0.339	1.251	118,513
Foot of Des Moines rapids, at Keokuk	70	11.12	1,036.43	475.59	22.17	1.994	1.162	118,705
Mouth of Des Moines river	71	2.90	1,039.33	473.64	1.95	0.672	1.161	133,395
Mouth of Fox river	72	3.14	1,042.47	471.97	1.67	0.532	1.159	133,995
Mouth of Wyaconda river	73	20.02	1,062.49	460.69	11.28	0.564	1.147	135,115
Mouth of Fabius river	74	13.21	1,075.70	455.03	5.66	0.428	1.139	137,226
Hannibal	75	15.31	1,091.01	448.21	6.82	0.445	1.136	137,460
Mouth of Salt river	76	26.62	1,117.63	434.97	13.24	0.497	1.114	140,791
Falmouth	77	29.55	1,147.18	420.90	14.07	0.476	1.098	141,794
Mouth of Cuivre river	78	17.92	1,165.10	412.34	8.56	0.478	1.088	143,000
Mouth of Illinois river	79	15.23	1,180.33	404.70	7.64	0.505	1.080	172,229
Above mouth of Missouri river	80	24.00	1,204.33	392.70	12.00	0.500	1.069	172,525
Mouth of Missouri river	81	0.00	1,204.33	392.70	0.00	.....	1.069	700,197
Saint Louis	82	17.00	1,221.33	379.18	13.52	0.795	1.065	700,663
Mouth of Meramec river	83	18.20	1,239.53	364.70	14.48	0.795	1.061	705,075
Mouth of Kaskaskia river	84	52.30	1,291.83	330.00	35.00	0.666	1.122	711,935
Mouth of Big Muddy river	85	34.60	1,326.43	307.00	23.00	0.666	1.035	715,116
Commerce	86	34.10	1,360.53	284.00	23.00	0.666	1.026	715,555
Mouth of Ohio river, at Cairo	87	32.80	1,393.33	262.00	22.00	0.666	1.018	929,914
Columbus	88	21.00	1,414.33	254.00	8.00	0.381	1.008	930,540
Mouth of Reel Foot river	89	102.70	1,517.03	213.00	41.00	0.399	0.967	932,418
Mouth of Forked Deer river	90	20.00	1,537.03	205.00	8.00	0.400	0.960	936,804
Mouth of Big Hatchee river	91	27.10	1,564.13	194.00	11.00	0.400	0.950	939,827
Mouth of Wolf river	92	52.20	1,616.33	173.00	21.00	0.400	0.957	941,559
Memphis	93	2.00	1,618.33	172.20	0.80	0.400	0.932	941,559
Mouth of Saint Francis river	94	70.20	1,688.53	144.00	28.00	0.400	0.909	950,443
Mouth of Arkansas river, at White river	95	102.30	1,790.83	107.00	37.00	0.362	0.879	1,140,246
Gaine's Landing	96	52.50	1,843.33	89.90	17.10	0.328	0.863	1,140,632
Lake Providence	97	89.25	1,932.58	65.29	24.61	0.276	0.778	1,141,403
Mouth of Yazoo river	9	60.25	1,992.83	49.29	16.00	0.266	0.818	1,154,583
Vicksburg	99	10.50	2,003.33	46.67	2.62	0.250	0.815	1,154,607
Mouth of Big Black river	100	49.25	2,052.58	35.63	11.04	0.224	0.801	1,158,469
Mouth of Big Pierre river	101	10.25	2,062.83	33.37	2.26	0.220	0.798	1,159,555
Natchez	102	49.50	2,112.33	23.97	9.40	0.190	0.784	1,160,249
Mouth of Homochitto river	103	42.75	2,155.08	16.70	7.27	0.170	0.772	1,161,747
Above mouth of Red river	104	19.25	2,174.33	13.70	3.00	0.156	0.766	1,162,209
Mouth of Red river, at Red River Landing	105	0.00	2,174.33	13.70	0.00	.....	0.766	1,259,209
Baton Rouge	106	71.00	2,245.33	7.37	6.33	0.089	0.745	1,260,261
Plaquemine, at mouth of bayou Plaquemine	107	22.75	2,268.08	5.66	1.71	0.075	0.738	1,260,346
Donaldsonville	108	29.25	2,297.33	4.01	1.65	0.056	0.729	1,260,547
New Orleans	109	79.00	2,376.33	2.35	1.66	0.021	0.710	1,261,084
Fort Saint Philip	110	77.00	2,453.33	1.55	0.80	0.010	0.684	1,261,416
Head of the passes	111	20.00	2,473.33	1.29	0.26	0.013	0.679	1,261,432
Mouth of the Mississippi	112	17.00	2,490.33	0.00	1.29	0.076	0.675	.....

etc., for various points on the Mississippi river—Continued.

Average annual precipitation above station.	Average annual precipitation, per second, on area above station.	FLOW, PER SECOND, PAST STATION.		FLOW, PER SECOND, PAST STATION, PER SQUARE MILE OF DRAINAGE AREA.		Ratio of average flow to average precipitation above station.	Ratio of ordinary low flow to average flow.	THEORETICAL HORSE-POWER AT STATION, UNDER AN ASSUMED HEAD OF 10 FEET.		Number of station.
		Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.			Ordinary low flow.	Average flow.	
Inches.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Per cent.*		*Horse-power.*	*Horse-power.*	
.....	199,504	26,130	62,234	0.298	0.710	31.1	0.420	29,644	70,604	61
.....	199,883	26,163	62,321	0.298	0.709	31.1	0.420	29,682	70,704	62
31.39	228,596	30,064	72,269	0.304	0.731	31.6	0.416	34,108	81,989	63
.....	229,356	30,125	72,436	0.304	0.731	31.5	0.416	34,177	82,179	64
32.27	265,933	33,303	81,199	0.291	0.726	30.5	0.411	37,782	92,120	65
32.31	269,683	33,630	82,056	0.297	0.724	30.4	0.410	38,152	93,093	66
.....	270,264	33,700	82,184	0.297	0.724	30.4	0.410	38,233	93,238	67
32.50	282,912	34,832	85,208	0.295	0.721	30.1	0.409	39,517	96,578	68
.....	283,899	34,914	85,425	0.295	0.721	30.0	0.409	39,610	96,915	69
.....	284,408	34,956	85,537	0.294	0.721	30.0	0.409	39,658	97,042	70
32.12	325,532	37,894	93,762	0.284	0.702	28.8	0.404	42,990	106,373	71
32.13	327,123	38,032	94,112	0.283	0.702	28.7	0.404	43,147	106,770	72
33.16	330,094	38,283	94,765	0.283	0.709	28.7	0.404	43,432	107,511	73
33.25	335,702	38,767	95,998	0.282	0.700	28.5	0.404	43,981	108,910	74
.....	336,306	38,818	96,131	0.282	0.699	28.5	0.404	44,039	109,061	75
33.22	344,670	39,550	97,972	0.281	0.696	28.4	0.404	44,869	111,149	76
.....	347,478	39,771	98,590	0.280	0.695	28.3	0.403	45,120	111,850	77
33.30	350,854	40,048	99,333	0.280	0.695	28.3	0.403	45,434	112,693	78
33.93	430,542	42,096	118,446	0.265	0.688	27.5	0.355	47,758	134,377	79
.....	431,349	42,161	118,624	0.265	0.688	27.5	0.355	47,832	134,599	80
23.13	1,193,271	.....	240,532	.....	0.344	20.1	.....	.....	272,884	81
.....	1,194,626	.....	240,857	.....	0.344	20.1	.....	.....	273,252	82
23.23	1,206,977	.....	244,060	.....	0.346	20.2	.....	.....	276,886	83
23.38	1,226,402	.....	249,084	.....	0.348	20.3	.....	.....	282,586	84
23.45	1,235,598	.....	251,453	.....	0.352	20.3	.....	.....	285,273	85
.....	1,236,659	.....	251,739	.....	0.352	20.3	.....	.....	285,598	86
27.98	1,917,379	.....	455,895	.....	0.490	23.7	.....	.....	517,213	87
.....	1,919,216	.....	456,538	.....	0.491	23.7	.....	.....	517,942	88
28.01	1,924,727	.....	459,018	.....	0.492	23.8	.....	.....	520,756	89
28.11	1,940,225	.....	466,006	.....	0.498	24.0	.....	.....	528,684	90
28.18	1,950,871	.....	470,847	.....	0.501	24.1	.....	.....	533,176	91
28.21	1,956,995	.....	473,663	.....	0.503	24.2	.....	.....	537,370	92
.....	1,956,995	.....	473,663	.....	0.503	24.2	.....	.....	537,370	93
28.34	1,984,467	.....	492,580	.....	0.518	24.3	.....	.....	558,831	94
28.35	2,381,444	.....	557,648	.....	0.489	23.4	.....	.....	632,643	95
.....	2,382,978	.....	557,918	.....	0.489	23.3	.....	.....	632,958	96
.....	2,386,047	.....	560,066	.....	0.491	23.4	.....	.....	635,395	97
28.66	2,437,819	.....	596,307	.....	0.516	24.4	.....	.....	676,510	98
.....	2,437,916	.....	596,375	.....	0.516	24.4	.....	.....	676,587	99
28.75	2,454,142	.....	605,577	.....	0.523	24.6	.....	.....	687,027	100
28.78	2,458,679	.....	608,114	.....	0.524	24.7	.....	.....	689,905	101
.....	2,461,490	.....	609,801	.....	0.526	24.7	.....	.....	691,829	102
28.83	2,467,721	.....	613,288	.....	0.527	24.8	.....	.....	695,775	103
.....	2,469,695	.....	614,472	.....	0.529	24.8	.....	.....	697,118	104
29.57	2,743,386	.....	664,544	.....	0.528	24.2	.....	.....	753,928	105
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	106
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	107
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	108
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	109
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	110
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	111
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	112

Table giving the drainage area, rainfall, discharge, power, etc., of the tributaries of the Mississippi river.

Stream.	Number of river.	Distance of mouth from source of the Mississippi.	Length.	Area of basin.	Average annual precipitation on the basin in rain and melted snow.					Average annual precipitation per second on the entire basin.	Discharge of river per second.		Discharge per second per square mile of drainage area.		Ratio of average discharge, to average annual precipitation on the basin.	Theoretical horse-power at mouth of river under an assumed head of 10 feet.	
					Spring.	Summer.	Autumn.	Winter.	Year.		Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.		Ordinary low flow.	Average flow.
		Miles.	*Miles.*	*Sq. M.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*P. ct.*	*H. P.*	*H. P.*
Mississippi above the Pinniddiwin river	1	.....	23	233	6.84	9.25	6.27	2.64	25.00	429	77	167	0.33	0.717	39	87	189
Pinniddiwin	2	33.8	17	151	6.84	9.25	6.27	2.64	25.00	278	50	108	0.33	0.715	39	57	123
East branch of the Mississippi	3	52.5	26	133	6.84	9.25	6.27	2.64	25.00	245	44	96	0.33	0.722	39	50	109
Turtle	4	80.5	40	300	6.84	9.25	6.27	2.64	25.00	552	102	232	0.34	0.773	42	116	263
Leech Lake	5	139.0	50	1,105	6.84	9.25	6.27	2.64	25.00	2,035	409	856	0.37	0.775	42	464	971
Prairie	6	191.9	19	491	6.84	9.25	6.27	2.64	28.00	904	147	380	0.30	0.774	42	167	431
Swan	7	230.9	49	349	6.84	9.75	6.27	2.64	25.50	656	105	276	0.30	0.791	42	119	313
Sandy Lake	8	271.9	.....	421	6.84	9.75	6.27	2.64	25.50	791	131	332	0.31	0.789	42	149	377
Willow and White Elk rivers	9	301.3	.....	547	6.84	9.75	6.27	2.64	25.50	1,028	159	411	0.29	0.751	40	180	466
Rice	10	318.9	24	293	6.84	9.75	6.27	2.64	25.50	550	88	220	0.30	0.751	40	100	250
Pine	11	355.9	140	961	6.84	9.75	6.27	2.64	25.50	1,805	288	722	0.30	0.750	40	327	819
Crow Wing	12	387.9	105	3,560	6.84	9.75	6.27	2.64	25.50	6,688	1,068	2,475	0.30	0.695	37	1,212	2,808
Sauk	13	439.9	82	968	6.55	11.38	5.49	2.58	26.00	1,854	290	593	0.30	0.613	32	329	673
Elk	14	484.1	100	587	6.55	11.38	5.49	2.58	26.00	1,124	158	337	0.27	0.591	30	179	382
Crow	15	489.1	141	3,085	6.18	12.30	6.81	2.71	28.00	6,364	926	2,036	0.30	0.660	32	1,051	2,310
Rum	16	497.3	136	1,539	6.23	11.58	6.61	2.58	27.00	3,061	462	918	0.30	0.596	30	524	1,041
Minnesota	17	523.6	256	16,027	7.03	11.75	6.60	2.62	28.00	33,060	2,500	7,604	0.156	0.474	23	2,836	8,627
Saint Croix	18	556.8	168	7,576	7.81	12.14	7.09	2.96	30.00	16,744	2,796	6,195	0.37	0.818	37	3,172	7,028
Cannon	19	577.8	90	1,492	7.21	12.04	6.84	2.91	29.00	3,188	433	893	0.29	0.599	28	491	1,013
Chippewa	20	610.8	165	9,573	8.39	13.87	7.94	3.80	34.00	23,978	3,542	8,872	0.37	0.927	37	4,018	10,065
Zumbro	21	617.8	80	1,346	7.21	12.04	6.84	2.91	29.00	2,876	377	748	0.28	0.556	26	428	849
Buffalo	22	622.6	50	468	8.12	13.57	7.63	3.68	33.00	1,138	131	296	0.28	0.632	26	149	336
Trempealeau	23	658.1	73	723	8.12	13.57	7.63	3.68	33.00	1,768	202	456	0.28	0.631	26	229	517
Black	24	682.6	166	2,272	8.39	13.87	7.88	3.86	34.00	5,691	750	1,992	0.33	0.877	35	851	2,260
Root	25	686.6	95	1,609	6.08	11.60	8.22	4.10	30.00	3,556	467	926	0.28	0.576	26	530	1,051
Upper Iowa	26	716.1	110	952	7.21	11.03	8.66	4.10	31.00	2,174	451	565	0.28	0.593	26	512	641
Wisconsin	27	757.6	407	12,280	8.57	12.79	8.21	5.43	35.00	31,663	4,790	11,399	6.39	0.928	36	5,434	12,932
Turkey	28	779.3	115	1,725	7.41	11.53	8.76	4.30	32.00	4,067	483	1,057	0.28	0.613	26	548	1,199
Maquoketa	29	840.7	116	1,904	9.51	11.72	8.90	5.87	36.00	5,050	514	1,313	0.27	0.690	26	583	1,490
Wapsipinicon	30	889.3	205	2,644	9.82	13.23	8.90	5.05	37.00	7,207	687	1,874	0.26	0.709	26	779	2,126
Rock	31	913.3	386	10,973	9.68	11.55	8.99	5.28	35.50	28,697	3,900	9,944	0.36	0.906	35	4,419	11,281
Iowa	32	963.7	326	12,466	8.03	16.63	9.33	5.01	39.00	35,816	3,117	8,596	0.25	0.690	24	3,536	9,752
Henderson	33	988.8	54	612	8.53	12.98	8.09	5.40	35.00	1,578	147	379	0.24	0.619	24	167	430
Skunk	34	999.3	243	4,427	9.88	13.23	8.84	5.05	37.00	12,067	1,062	2,896	0.24	0.654	24	1,205	3,286
Des Moines	35	1,039.3	402	14,690	9.88	14.31	9.60	4.21	38.00	41,124	2,938	8,225	0.20	0.560	20	3,333	9,331
Fox	36	1,042.5	62	600	10.34	11.08	8.45	6.13	36.00	1,591	138	350	0.23	0.583	22	157	397
Wyaconda	37	1,062.5	85	501	10.34	11.08	8.45	6.13	36.00	1,329	115	292	0.23	0.583	22	130	331
Fabius	38	1,075.7	98	1,987	10.34	11.08	8.45	6.13	36.00	5,270	457	1,159	0.23	0.583	22	518	1,315
Salt	39	1,117.6	185	3,044	9.34	10.58	8.10	5.98	34.00	7,625	669	1,678	0.22	0.551	22	759	1,904
Cuivre	40	1,165.1	99	1,196	10.54	11.88	8.45	7.13	38.00	3,348	275	737	0.23	0.616	22	312	836
Illinois	41	1,180.3	397	29,013	10.31	11.79	8.51	6.39	37.00	79,083	2,000	18,980	0.07	0.654	24	2,269	21,533
Missouri	42	1,204.3	2,908	527,672	6.10	6.40	4.40	2.70	19.60	761,922	.....	121,908	.....	0.231	16	.....	138,305
Meramec	43	1,239.5	217	4,098	11.67	11.13	8.54	6.66	38.00	11,472	.....	2,983	.....	0.728	26	.....	3,384
Kaskaskia	44	1,291.8	280	5,876	11.87	11.38	8.54	7.21	39.00	16,743	.....	4,353	.....	0.741	26	.....	4,938
Big Muddy	45	1,326.4	127	2,374	11.97	11.48	8.94	7.61	40.00	6,996	.....	1,819	.....	0.766	26	.....	2,064
Ohio	46	1,393.3	1,265	214,000	11.90	11.80	8.50	10.90	43.10	679,488	.....	203,846	.....	0.953	30	.....	231,263
Forked Deer	47	1,537.6	92	4,306	16.91	11.33	8.24	11.52	48.00	15,227	.....	6,852	.....	1.591	45	.....	7,774
Big Hatchee	48	1,564.1	128	2,726	16.91	11.33	8.24	11.52	48.00	9,640	.....	4,338	.....	1.591	45	.....	4,921
Wolf	49	1,616.3	72	1,392	16.91	11.33	8.24	11.52	48.00	4,922	.....	2,215	.....	1.591	45	.....	2,513
Saint Francis	50	1,688.5	380	7,989	12.40	10.20	8.60	10.30	41.30	24,307	.....	17,015	.....	2.130	70	.....	19,304
Arkansas	51	1,790.3	1,514	189,000	8.55	9.33	6.33	4.08	28.30	394,019	.....	63,000	.....	0.333	16	.....	71,075
Yazoo	52	1,992.8	500	12,794	17.79	10.94	8.90	15.67	53.30	50,237	.....	35,166	.....	2.749	70	.....	39,896
Big Black	53	2,052.6	444	3,406	18.30	12.20	10.30	16.50	57.30	14,378	.....	7,908	.....	2.322	55	.....	8,962
Big Pierre	54	2,062.8	109	1,018	17.90	12.30	10.30	16.30	56.80	4,261	.....	3,344	.....	2.303	55	.....	2,659
Homochitto	55	2,155.0	106	1,201	17.90	12.30	10.30	16.30	56.80	5,027	.....	2,765	.....	2.301	55	.....	3,137
Red	56	2,174.3	1,200	97,000	11.51	10.22	8.44	8.15	38.30	273,691	.....	50,000	.....	0.515	22	.....	56,725

EXPLANATION AND DISCUSSION OF THE TABLES OF FLOW, RAINFALL, ETC.

A report upon the water-power of the Mississippi basin is not complete without some consideration of the meteorological and topographical conditions which so greatly affect it. The valley of the Mississippi, including as it does the entire central portion of the United States, embraces every variety of climate from the semi-tropical to one of almost arctic winters, the rainfall varying from that of the arid desert to the heavy down-pour of a torrid clime; and it contains within its extensive boundary the rugged mountain range, the forest, the broad treeless plain, the cultivated farming land, and the wild southern swamp, thus explaining the wide differences in the character of the rivers.

The original aim was to collect well-certified facts, and from them to deduce results. To a great extent, and so far as possible, this has been carried out; but further investigation showed the utter impracticability of relying on this method in every case, because sometimes absolutely no data could be obtained. In such cases resort was had to comparison, and just here was another difficulty: There are few if any places in the west where long-continued and frequent gaugings of the streams have been made, and the conditions there are so different from those usual in the eastern states that the results obtained from the one cannot be applied with any certainty to the other. However, the endeavor was made to do the best possible under the circumstances, and in describing the tables it will be shown how, to a certain extent, a test is applied to the calculations, checking the results. Enough actual data were available and were used, to inspire the confidence that, at least for general results, the conclusions reached may be relied upon; and in order that those who are sufficiently interested to take the pains may satisfy themselves in the matter, the methods and facts made use of are described where practicable.

No one, unless he has undertaken a task of a similar character, can understand the difficulty of reaching conclusions from the mass of apparently conflicting testimony; and especially is this true in the west, where until within recent years most of the few measurements that have been made of the streams have been inacurate, and are of no avail because insufficiently described. A few years more will probably see a great increase in the amount and value of the data regarding stage and flow, at least for the Mississippi and the Missouri, for the Mississippi River commission and the government engineers in charge are now engaged in systematic gaugings at various points.

It is a pleasure to acknowledge the invariable courtesy of the United States engineers connected with the river improvement, without whose kind assistance in furnishing material the preparation of these tables would have been impossible.

A set of calculations has been made for the tributaries of the Mississippi, and embodied in the second table. From those are deduced the results for the main river, which are given in the first table. Data furnished from the United States engineers' offices and government reports, where obtainable, have been given credence above all others. The method of arriving at the amounts placed under the various headings will now be described.

In making the list of tributaries, each one having a drainage area of 500 square miles or over has been included, and several, at the upper waters, of smaller size. The total number taken is 56. In selecting stations upon the main river, the mouths of all the above-mentioned tributaries have been included, and also such other points as, from their position with reference to the physical features of the river, or their relation to surveys and river gaugings, will be of value. The total number of stations is 112.

Distances.—Distances along the river course were thus obtained: A table of distances from Saint Paul up to Cass lake was furnished by Major Charles J. Allen, stationed at Saint Paul; the report for 1880 of Captain A. Mackenzie, stationed at Rock Island, contains a table of distances from Saint Paul to the mouth of the Illinois river, which was used; below that the distances were taken partly from Humphreys and Abbot's report, partly from the various reports of the chief of engineers. Above Cass lake the only published distances, so far as known, are those estimated by Nicollet, and also by Schoolcraft. The estimates of the former are used by Humphreys and Abbot, but, as is mentioned by them, are undoubtedly too great. No meanderings have been made above Cass lake; and, in their absence, it was concluded best to measure the course of the stream as closely as possible from the map of the state of Minnesota, made on a scale of 6 miles to the inch. This places the outlet of lake Itasca 65 miles above the head of Cass lake, while, according to Nicollet, the distance is 135 miles. It is probable that 65 miles is somewhat less than the true amount. In order to obtain the distance of any station in the tables from the source of the river according to Nicollet's estimates, it is only necessary to add 70 miles to the distance given. The length of the river would then appear as 2,560 miles, instead of 2,490.

Below Cass lake the distances can lay claim to greater accuracy. The plan pursued was to take the positions of all points mentioned in the several surveys and insert most of them in the tables. Intermediate stations were determined by taking the surveyed distances and dividing them in proportion to the distances as measured, either upon the United States engineer's survey maps or upon the maps of the United States land office. It must be remembered that the course of the river is changing and cut-offs are occurring, which may have slightly altered its length since the surveys of Humphreys and Abbot were made. The lengths of the tributaries have been taken,

where possible, from the reports of the United States engineers All others were measured from large state maps or from the United States land office maps. Judging from tests made, the latter estimates are somewhat less than the true amounts.

Elevations.—Considerable difficulty is experienced in tabulating a complete series of levels for the Mississippi. No complete survey has ever been made of the entire stream, and the detached surveys do not agree with each other. This is not much to be wondered at. The surface of the upper river is usually connected with the levels of the great lakes by means of railroad levels, and the levels of the lower river are mainly carried upward from the Gulf. The variation in the height of the water-surface is 10 or 12 feet near the mouth, as much as 50 feet about the Ohio river, and from 10 to 20 feet upon the upper river. Apparently there has not been much concerted action, until recent years, in the use of the river-gauges, and it is hard to decide from the records to just what stage any series of levels is referred, while a comparatively small fluctuation in the river will have a considerable effect upon the level of the water-surface. We are prepared, then, to find a discrepancy of several feet between two independent surveys.

Our aim is to give a complete series of elevations from the source to the mouth at an *ordinary low* stage of the river. The levels available divide the river into four sections: 1, from the source to Cass lake; 2, from Cass lake to Saint Paul; 3, from Saint Paul to Grafton, at the mouth of the Illinois; 4, from the mouth of the Missouri to the Gulf.

The best levels obtainable for the first section are those taken by Nicollet with a barometer in 1836; they are those used by Humphreys and Abbot. Major Allen supplies a list of levels for section 2, presumably at ordinary low water of an average year. Captain Mackenzie gives in his report a table of elevations for section 3, reduced to the low water of 1864 (an extremely low year). For section 4 "precise levels" are furnished by the Mississippi River commission for five points. They must nearly represent an ordinary low stage of the river. No levels were found connecting the Missouri and the Illinois rivers. The first set places Cass lake 1,402 feet above the sea; the second set places Cass lake 1,300.1 feet above the sea, and Saint Paul 682 feet above the sea; while the third set places Saint Paul 678 feet above the sea; the fourth set places the mouth of the Missouri 392.7 feet above the sea; while the third set, by prolonging the slope of the upper Mississippi below the mouth of the Illinois, would place the mouth of the Missouri 387.32 feet above the sea-level.

The relative levels of the different stations of the same survey are undoubtedly nearly correct, and the only course seems to be to take one set of levels as a starting point, and reduce the other series to accord with it, preserving their individual relations. Accordingly the levels obtained from the Mississippi River commission have been selected, and the others reduced so as to agree with them.

The only levels of the commission in my possession are those for the mouths of the Red, Arkansas, Saint Francis, and Missouri rivers. For intervening points the low-water slopes, as determined by Humphreys and Abbot for the years 1851 and 1855 are employed, increasing or diminishing them proportionately, as the case may require.

The distance from the Missouri to the Illinois river is 24 miles, and from the two surveys the difference in elevation, 6.74 feet, or 0.26 foot per mile, is very small. The slope above the mouth of the Illinois is 0.515 foot per mile, or approximately 0.5 foot per mile, to the Missouri river, this would make the elevation of the mouth of the Illinois 404.7 feet, or 5.26 feet more than that given by the survey of section 3. The water was at an *exceedingly* low stage and the elevation at an *ordinary* low stage would be greater. To each of the elevations of survey No. 3, 5.26 feet are added. This makes Saint Paul 1.26 feet higher than the elevation given in survey No. 2; hence 1.26 foot are added to each of the elevations of that survey. Above Cass lake the elevations are approximate. Nicollet's estimates for the source of the river and lake Itasca agree well with elevations taken in the basin of the Red river of the North and are adopted. The slope from Cass lake to the mouth of the Pinniddiwin is assumed from Schoolcraft's description of the river's course to be about 12 inches per mile. Major Allen's estimate of 1,300.1 feet+126 feet, is assumed as the elevation of Cass lake. The difference of about 100 feet between Nicollet's estimate of the level of Cass lake and Major Allen's survey is assumed to be included in the fall from lake Itasca to the Pinniddiwin river, which, from Schoolcraft's description of the severe rapids, does not seem at all improbable.

It is evident that to carry the difference of 5.26 feet unchanged from Grafton to Saint Paul, and of 1.26 foot from Saint Paul to Cass lake, cannot possibly give absolutely correct elevations, but it is the best that can be done, and is certainly within the limits of fluctuation of the water-surface. The slope as given in the surveys is retained, which is the chief point, and it is only necessary to subtract either 1.26 foot, or 5.26 feet, as the case may be, from the amounts in the column of elevations to get the figures of the surveys. For points intermediate of the stations of the surveys the elevations were found approximately by distributing the difference in level proportionately to the distances.

The columns giving the slope of the water-surface in feet per mile are obtained from the preceding ones.

Drainage areas.—The drainage areas of the tributaries and of the main river were measured expressly for this report, with the exception of those of the Missouri, Ohio, Arkansas, and Red River basins. In the case of the Missouri, the estimate made by Major Suter, corps of engineers, U. S. army, was used. Major Suter is stationed

at Saint Louis, and is engaged upon a very complete report on the Missouri; and his estimate for the Missouri basin, 527,672 square miles, is probably more nearly correct than that of 518,000 square miles, made for the report of Humphreys and Abbot twenty years earlier.

The drainage areas of the Ohio, Arkansas, and Red rivers are taken from Humphreys and Abbot's report; and the chief of engineers at Washington states that he has no more reliable data on these rivers in his possession.

All the other areas, as stated above, were measured. For this purpose an accurate planimeter, reading to hundredths of a square inch, was used. The areas were taken from the United States land-office maps, made on scales varying from 12 to 18 miles to the inch. The only exception was in the case of the small streams entering the Mississippi from Kentucky and Tennessee. The land-office has not published maps of those states, and a map on a scale of 12 miles to the inch, accompanying J. D. Killebrew's report on the resources of Tennessee, was used for that state; while, for Kentucky, a map on a scale of 26½ miles per inch, prepared for the *Eclectic Geographies*, was employed.

In drawing the lines of water-shed they were made to meet at the mouth of each river. Where large tracts occur, as is frequently the case in flat countries, with no well-defined limits of drainage, the area was divided as nearly as possible proportionately between the neighboring streams. From the mouth of one tributary to the next there is frequently a large tract draining by small brooks directly into the Mississippi. These areas, which we may call *brook areas*, are not included in the drainage basins of the tributaries, and were measured separately. By a proper comparison of the two tables their amounts can be ascertained. There are 17,673 square miles of this brook area tributary to the upper Mississippi; and the entire amount tributary to the Mississippi, as calculated for this report, is 31,710 square miles. The column giving the drainage area above stations on the main river was obtained by adding these brook areas to the drainage areas of the tributaries.

The planimeter was several times tested on accurately known areas, all large measurements of over 3,000 or 4,000 square miles were duplicated, and the amounts given are thought to be very closely correct for the areas as given on the land-office maps.

The total area of the Mississippi basin is estimated to be, in round numbers, 1,261,400 square miles. The report of Humphreys and Abbot states it to be 1,244,000 square miles, 1.38 per cent. less, about one-half of this difference occurring in the Missouri basin estimates. The calculations give 3,525 square miles more drainage area to the upper Mississippi than is recorded by Humphreys and Abbot.

RAINFALL, ETC.

The tables published by the Smithsonian Institution, of Washington, in May, 1881, have been used in estimating the *average* annual precipitation in rain and melted snow upon the Mississippi basin. The course pursued was to plot upon the land-office maps, in its proper place, the amount of annual precipitation for each station as given in the rain tables, and the number of years of observation. By careful comparison of the figures plotted within each river basin, taking account of the number of years of observation, and by comparing these figures with the rain charts in the book, the average precipitation upon the basin of each tributary of the Mississippi was estimated. For the Missouri, Ohio, Arkansas, and Red River basins, the figures were plotted upon a small map of the United States, and the different basins were divided into sections of equal area and nearly similar rainfall. The average precipitation was ascertained for each of these sections, and then for the entire basin. The distribution of the precipitation according to the seasons was estimated by comparing the rainfall charts for each of the four seasons, and also the tabulated rain gaugings. The most elaborate discussion of the rainfall of the Mississippi basin in relation to the systems of drainage, so far as known, is that of Humphreys and Abbot. They pursued much the same course as that mentioned above, but the data at their command were not nearly so complete as those furnished in the publications of the Smithsonian Institution. Their results and those obtained for this report agree substantially, with the exception of the estimates for the Yazoo basin. They state its average precipitation to be 46.3 inches per annum, while it is here considered to be about 53.3 inches. The reason of this difference is apparent: Humphreys and Abbot had at their disposal the records of only three stations, Memphis, Vicksburg, and Jackson, of which Memphis had a precipitation of only 41.8 inches. This, in averaging the records, gave too low a result, as plainly indicated by the Smithsonian Institution publications.

Discussion of geographical variations of the rainfall.—A comparison of the table of tributaries shows a somewhat uniform increase in the amount of precipitation from the source to the mouth of the Mississippi in the vicinity of its immediate valley. Starting with barely 25 inches at the source, it increases to nearly 60 inches at the Gulf. If, however, we include in the comparison the large tributaries great variations occur; and this is plainly shown by the average precipitation column of the table of the main river, as also by the curve plotted on the curve-sheet. The average on the basin of the Mississippi above the Missouri gradually increases to 33.93 inches; the Missouri, with its precipitation of only 19.6 inches, lowers it to 23.13 inches. The Ohio, with its precipitation of 43.1 inches, raises the average to 27.98 inches. The Arkansas, with its precipitation of 28.3 inches, just maintains the average above its mouth, although much below the rainfall at its mouth. The Red river, which has an annual precipitation of 38.3 inches, is also below the rainfall at its mouth, but nevertheless raises the average of the entire basin from 28.83 to 29.57 inches.

Variation due to the seasons.—The above are the prominent features of the yearly precipitation. The changes in the distribution of the precipitation through the four seasons as we pass through the Mississippi basin are very unlike. The *average* precipitation for the different seasons on that portion of the basin above the successive stations on the main river has not been given, because of the time required to determine more than a very rough approximation. For the basins of the various tributaries, however, it is given in the second table, and a general idea can be obtained from it for the entire Mississippi basin. In the same way as for the total precipitation, a comparison of the distribution for the smaller tributaries shows a rather uniform change from the source to the mouth, while the large tributaries appear in the columns, with variations from the surrounding figures more or less pronounced.

Variation along the main river.—Considering the smaller tributary basins only, and dividing the length of the main river into four equal sections, we have the following *approximate* results for the distribution of the precipitation:

Region.	AVERAGE PRECIPITATION OF RAIN AND MELTED SNOW.				
	Spring.	Summer.	Autumn.	Winter.	Year.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Source	6.84	9.25	6.27	2.64	25.00
First quarter	7.21	12.04	6.84	2.91	29.00
Second quarter	9.93	13.23	8.84	5.50	37.50
Third quarter	13.37	11.36	8.54	9.30	42.57
Fourth quarter	16.00	10.93	9.10	14.10	50.13
Mouth	18.30	12.20	10.30	16.50	57.30

This shows that toward the mouth the winter and spring precipitation is immensely greater, relatively to the summer and autumn rains, than near the source, and this change takes place along the entire course of the river. In the first quarter, the summer and autumn precipitation is 18.88 inches; the winter and spring precipitation is 10.12 inches. In the fourth quarter, the summer and autumn precipitation is 20.03 inches; the winter and spring precipitation is 34.80 inches.

Variation in the large tributary basins.—Turning, now, to the four large tributaries, we find these results:

River.	ANNUAL PRECIPITATION OF RAIN AND MELTED SNOW.				
	Spring.	Summer.	Autumn.	Winter.	Year.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Missouri	6.10	6.40	4.40	2.70	19.60
Arkansas	8.55	9.33	6.33	4.08	28.30
Red	11.51	10.22	8.44	8.15	38.30
Ohio	11.90	11.80	8.50	10.90	43.10

The distribution on the Missouri basin, so far as the four seasons are concerned, is very similar to that at the sources of the Mississippi. The distribution on the Arkansas basin is of much the same character. For the Red River basin the winter and spring precipitation exceeds that of summer and autumn by one inch in depth, and the distribution partakes more of the nature of that at the mouth of the main river. In the Ohio basin the distribution is more like that existing at the mouth of the main river than is the case with any of the other rivers mentioned, the winter and spring precipitation exceeding the summer and autumn rainfall by 2.5 inches. There is apparently a tendency for the lower of the large tributaries to have a greater precipitation in winter than in summer, while this tendency is not so strong toward the north. In this respect they resemble the immediate Mississippi valley.

Summary of facts.—Summing up all the evidence, we have this result: A light precipitation at the sources of the river, gradually increasing toward the south; a very light precipitation on the western portion of the basin, about the upper waters of the Missouri, the Arkansas, and the Red rivers; very little change in the amount of precipitation on passing eastward through the Ohio basin. As regards the distribution of this annual precipitation according to the seasons, there is a preponderating summer precipitation at the sources, but a gradual increase in the winter precipitation relatively to that of the summer toward the south, until at the mouth the winter precipitation is much the greater of the two: A greater summer than winter precipitation at the west, upon the basins of the Missouri and Arkansas especially, while nearly equal proportions prevail within the Red River basin; a greater precipitation in winter and spring than in summer and autumn on the basin of the Ohio.

Physical causes of the above facts.—The causes of these peculiarities are readily traced. The ocean is the great reservoir from which is drawn the moisture that waters the earth. The warm Pacific current, accompanied by moisture-bearing winds, strikes the western coast of the United States and British America and forms one source of supply; the Atlantic also, to some extent, feeds the air with vapor which falls on the United States; but the gulf of Mexico, lying under a semi-tropical sun, is the great evaporating surface from which are obtained the rains of our country. The saturated southerly and southwesterly winds blow up the valley of the Mississippi, and meeting

no abrupt changes in the contour of the country, deposit their moisture in a broad sheet, extending beyond the northern confines of the United States, and to some extent westward over the plains east of the Rocky mountains; but as the anti-trades, of which these winds are a part, are essentially southwest winds, the prevailing tendency is for the line of maximum precipitation due to them to take a northeast direction across the Ohio basin and into the Atlantic states.

The moisture-bearing winds from the Pacific are largely deprived of their moisture by the chilling contact of the western ranges of mountains, and after passing these and entering the warmer region eastward their capacity for retaining moisture is increased, so that very little rain or snow falls from them upon the dry regions of the western portion of the Mississippi basin.

To this influence of the barrier of the western ranges of mountains, in checking the flow of vapor from the Pacific ocean, is due the light annual precipitation of from 6 to 14 inches about the headwaters of the Missouri, Arkansas, and Red rivers. To the action of the moist winds from the Gulf is due the precipitation of the Mississippi basin, which gradually diminishes toward the north as the south winds become drier, and more rapidly toward the west, where the rainfall mentioned is largely due to it.

The variation in the distribution of this precipitation, which has already been described, is due to the passage of the sun to the southern hemisphere, or *vice versa*. There are two contending forces in the temperate zone—these warm moisture-bearing winds just described, and the cold, dry winds from the north. When they meet, the result is the condensation of the moisture of the southern winds, and rain or snow, as the case may be. When the sun is far up in the north and summer prevails in the northern hemisphere, then the moist winds encroach upon those from the north, and the result is that the larger part of their moisture is carried beyond the southern part of the Mississippi basin and precipitated farther north. As the sun sinks lower in the southern horizon and winter sets in, the cold winds gain the ascendency, and the result is that comparatively little precipitation occurs in the northern portion of the Mississippi basin, while on the other hand the southern part of the basin is receiving the bulk of its annual rainfall, and thus this belt of heaviest precipitation swings north and south, season after season, following the sun in its changes of declination. The winter precipitation on the Ohio basin almost exceeds that of summer. On the large western tributaries, however, the cold winds easily gain the mastery, and at their upper waters the winter precipitation is consequently very light.

FLOW OF THE STREAMS.

In studying this branch of the hydrology of the Mississippi basin the two tables have been necessarily considered together. The principle has been to collect all the actual gaugings obtainable of the main river and its branches at various points, and from these to determine as nearly as possible the flow of each tributary, and of the main river at each of the stations given in the table. Comparisons have then been made with the rainfall, etc., and ratios deduced. Only two stages of flow have been selected, viz., the ordinary low flow and the average flow. There are several reasons for this—the gaugings in the west are so few as to make great detail of discussion an impossibility, and the two stages selected are the only two of prime importance to the interests of water-power. No division of the subject into monthly flow and comparison with the monthly rainfall has been attempted, because, while such a course is possible for many eastern streams, where long series of measurements have been made, it is impracticable for the streams under discussion.

Definitions of ordinary low flow and average flow.—The ordinary low flow is intended to represent the average flow during a period of twenty or thirty days in the late summer or fall, when the river is lowest. A record of monthly stages for five years at Rock Island shows the month of lowest stage to have been September. At Saint Paul and above it is probable that the lowest stages occur in midwinter; but no gaugings have been made of the flow at that time, and it must be understood that *the calculations given for the ordinary low flow in that region are not applied to the winter months*, although, as moderate estimates are used, it is probable that they are not greatly in excess even for that period.

In making calculations at the engineer's office at Saint Paul the average flow of the Mississippi at Minneapolis for the 134 days from November 17 to April 1 was taken at 5,000 cubic feet per second. The tables give the ordinary low flow at Minneapolis as 6,017 cubic feet per second. The ordinary low flow of the main river has not been carried in the tables below the Missouri river, as below that point the large tributaries come from such far-distant sources that, while one is at low stage, another may be running with overflowed banks, and there is no certainty of an ordinary low stage existing throughout the drainage system at any one time. With the average flow, however, the case is different. That represents the stage of the river if we presume it to remain constant from one day to another all the year through, and is practically the actual condition that would exist if a perfect and uniform system of reservoirs was applied throughout the entire Mississippi basin, so that the floods could be held back and distributed during the low-water seasons. Whether such a system of reservoirs is practicable, is another matter. To a certain extent it is, and this makes the average flow of great importance in the consideration of the water-power.

The recorded gaugings at Saint Paul and above were made under the direction of Major Charles J. Allen, with the exception of those for the Minnesota river. Those for the main river, from Saint Paul to the mouth of

the Illinois, were furnished by Captain Alex. Mackenzie, stationed at Rock Island. The gaugings of the main river below the Missouri are taken from the elaborate report of Humphreys and Abbot.

ORDINARY LOW FLOW.

Flow of main river above the Minnesota.—Above the mouth of the Minnesota river all the gaugings employed were made on the main river itself. The first below the source was made at Grand Rapids. A gauging made there October 13, 1880, reduced to a mean low stage, gave 1,058.5 cubic feet per second. Three gaugings made October 15, 1879, at 0.4 of a foot below mean low-water, gave an average of 969 cubic feet per second, from which we estimate the mean low flow to be 1,065 cubic feet per second. The table gives an ordinary low flow at Grand Rapids of 1,036 cubic feet per second. Four gaugings made at Aitken, below the mouth of Rice river, October 20, 1879, at a stage 0.2 of a foot below mean low water, give an average flow of 1,743 cubic feet per second, from which we estimate the mean low flow to be 1,863 cubic feet per second. The table indicates an ordinary low flow past Aitken of almost precisely the same amount. Daily gaugings were made at Brainerd, Sauk Rapids, and Fridley's bar just above Minneapolis, through the spring, summer, and fall of 1875. The lowest stage at Brainerd was in August, when for eleven days the flow varied between 3,000 and 2,700 cubic feet per second. At Sauk Rapids the low stage ran for sixteen days from 4,327 cubic feet to 4,753 cubic feet per second. At Minneapolis the low stage varied for twenty-eight days between the limits of 5,640 cubic feet and 7,177 cubic feet per second, with an average of about 6,600 cubic feet per second. The table gives an ordinary low flow per second past these stations of 2,246, 4,123, and 6,017 cubic feet, respectively. The results given in the table for the first two places are probably low estimates of the ordinary low flow; they certainly are such for the year 1875, which was not far from being an average year as regards rainfall. For Minneapolis the amount given in the table is somewhat nearer the gaugings for 1875.

"High-flow" and "low-flow" streams.—The United States engineers' reports state the average low flow of the Saint Croix river to be 2,796 cubic feet per second, giving a flow per square mile of 0.369 cubic foot per second; and of the Wisconsin 4,790 cubic feet per second, giving a flow per square mile of 0.39 cubic foot per second. We will be on the safe side if we assume these figures for the *ordinary low flow*, as previously defined.

The Rock river has been gauged near its mouth for the purposes of water-power, and its ordinary low flow determined to be 3,900 cubic feet per second, or 0.355 cubic foot per second per square mile of drainage area.

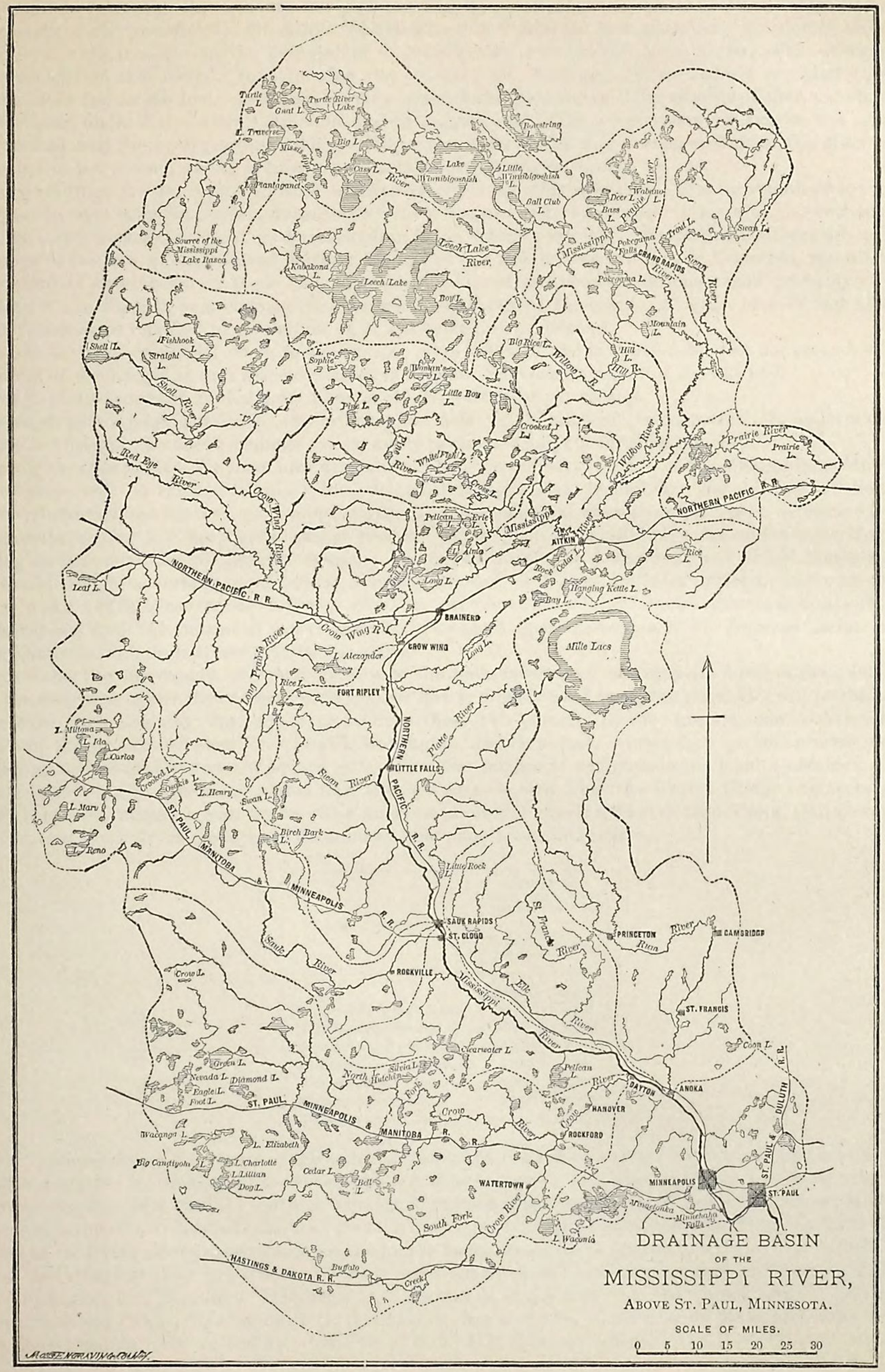
The Minnesota river is a very variable stream, and while its discharge rises to 60,000 cubic feet per second, it sometimes falls as low as 800 cubic feet per second; but from the gaugings made under General G. K. Warren it is concluded to call the ordinary low flow 2,500 cubic feet per second, or 0.156 cubic foot per second for each square mile of drainage area.

There are two classes under which, for convenience, we can range the tributaries of the upper Mississippi, with, of course, some intermediate cases. These are what may be called high-flow streams, like the Saint Croix, etc., flowing from a swampy and wooded region, giving an ordinary low flow of over 0.3 cubic foot per second per square mile; and low-flow streams, like the Minnesota, draining a prairie country and giving an ordinary low flow of less than 0.3 cubic foot per second per square mile.

The Chippewa basin has features similar to those of the basins of the Saint Croix and Wisconsin rivers; and, considering the rainfall, etc., the flow has been estimated at 0.37 cubic foot per second per square mile, which certain gaugings indicate to be approximately correct. The basin of the Black river is likewise considered, from similar reasons, to give an ordinary low flow of 0.33 cubic foot per second per square mile. These two rivers are included among the high-flow streams.

Flow of the upper Mississippi below the Minnesota.—The following data concerning the volume of flow and corresponding stage of the Mississippi at points between Saint Paul and the Illinois river are collected from material furnished by Captain Mackenzie. The adopted low-water volumes represent an extreme low flow, not an ordinary low flow in the sense in which we use the term:

Locality.	First tributary above station.	Stage.	Width.	Flow per second.	Adopted low-water flow per second.
		Feet.	*Feet.*	*Cubic feet.*	*Cubic feet.*
Frenchman's bar	Minnesota	5.8	.....	20,091	5,000
Wabasha	Chippewa	3.5	1,500	21,212	10,000
Johnsonport	.....	1.0	1,570	16,473	14,000
Below mouth of Wisconsin river	Wisconsin	0.96	1,237	20,527	17,000
Lyons	Maquoketa	3.10	1,736	37,512	18,500
Princeton	Wapsipinicon	1.1	2,087	27,743	19,000
Rock Island	do	2.1	2,444	30,313	19,000
		18.4	2,737	251,348	19,000
Burlington	Henderson	7.2	2,406	103,536	22,000
		0.7	2,333	27,929	22,000
Canton	Fox	5.2	2,339	61,445	26,000
Hannibal	Fabius	1.5	1,100	38,741	30,000


DRAINAGE BASIN
OF THE
MISSISSIPPI RIVER,
ABOVE ST. PAUL, MINNESOTA.
SCALE OF MILES.
0 5 10 15 20 25 30
Turtle L.
Goat L.
Turtle River Lake
L. Traverse
Big L.
Lake Winnibigoshish
Little Winnibigoshish L.
Bolstring L.
Ball Club L.
Deer L.
Bass L.
Prairie River
Wabana L.
Trout L.
Swan L.
Swan River
Pokegama Falls
GRAND RAPIS
Pokegama L.
Mississippi
L. Plantagenet
Source of the Mississippi Lake Itasca
Leech Lake River
Kabakona L.
Leech Lake
Boy L.
Mountain L.
Shell L.
Fishhook L.
Straight L.
Shell River
L. Sophie
Big Rice L.
Willow R.
Hill L.
Hill R.
Little Boy L.
Pine L.
Crooked L.
Pine River
Willow River
Prairie River
Prairie L.
Red Eye River
Crow Wing River
Pelican L.
Erie L.
NORTHERN PACIFIC R.R.
AITKIN
Rice L.
Leaf L.
Gull L.
Long L.
Rock
Cedar L.
Hanging Kettle L.
Bay L.
BRAINERD
CROW WING
L. Alexander
Long Prairie River
Mille Lacs
Rice L.
FORT RIPLEY
NORTHERN PACIFIC R.R.
Plate River
L. Miltona
L. Ida
L. Carlos
Crooked L.
Osakis L.
L. Henry
Swan L.
Swan River
LITTLE FALLS
L. Mary
L. Reno
ST. PAUL, MANITOBA & MINNEAPOLIS R.R.
Birch Bark L.
Little Rock L.
SAUK RAPIDS
ST. CLOUD
St. Francis River
PRINCETON
Rum River
CAMBRIDGE
Saul River
ROCKVILLE
Elk River
ST. FRANCIS
Crow L.
Clearwater L.
Coon L.
Green L.
Nevada L.
Diamond L.
Eagle L.
Foot L.
Silvia L.
North Fork
Hutchin
Pelican L.
DAYTON
ANOKA
ST. PAUL & DULUTH R.R.
HANOVER
ROCKFORD
Wacanga L.
L. Elizabeth
Big Cauttyohn L.
L. Charlotte
L. Lillian
Dog L.
Cedar L.
Bell L.
WATERTOWN
MINNEAPOLIS
ST. PAUL
Minnetonka
Minnehaha Falls
South Fork
Crow River
L. Waconia
HASTINGS & DAKOTA R.R.
Buffalo Creek

In order to determine the ordinary low flow we will have to resort to approximation, by making use of measurements of the water-level. Of course the amount of flow does not bear a simple proportion to the stage of the river; yet while it would not be permissible to consider the average flow to equal that at the average stage, the employment of this method to determine the ordinary low flow may be reasonably expected to yield a somewhat close approximation. As a test, we may apply the method to the daily records of flow and stage made at Fridley's bar, under Major Allen's direction, during August, 1875. The average flow for August was 6,695 cubic feet per second, and the average stage 0.661 foot above low water. The flow corresponding to the stage is about 6,635 cubic feet per second, giving a difference of only 60 cubic feet per second.

Gauge-readings for five years at Rock Island, reduced to monthly averages, show the month of lowest stage for the year to have been September, during which the average was 1.44 foot above low water. It is thought that this can be safely assumed as the stage corresponding to the ordinary low flow. Unfortunately there are no records of gaugings of the flow at Rock Island during the stage of 1.44 foot, but we can turn to Princeton, just above. No large tributaries enter between these two places, and a rise of 1.44 foot at the one would probably, from the dimensions of the channel, be accompanied by a nearly equal rise at the other. A stage of 1.10 foot above low water at Princeton is reported to give a flow of 27,743 cubic feet per second.

A stage of 1.44 foot carried down to Burlington, gives a flow of about 35,000 cubic feet per second, according to the curve of discharges at that place contained in Captain Mackenzie's report of July 7, 1880.

A stage of 1.5 foot at Hannibal gave a flow of 38,741 cubic feet per second.

Although only approximations to the ordinary low flow, yet, because of the comparatively uniform nature of the upper Mississippi, the above amounts can be safely taken as being not far from the truth.

Flow of the tributaries.—We have now determined upon the ordinary low flow of the Mississippi at Minneapolis (the flow above will be considered later), Rock Island, Burlington, and Hannibal. The ordinary low flow of the high-flow tributaries, the Saint Croix, Chippewa, Black, Wisconsin, and Rock rivers, has been determined; also of the Minnesota among low-flow rivers. What remains to be done is to determine the ordinary low flow of the remaining rivers, which are all low-flow streams. So far as known, no gaugings by the United States engineers are obtainable for these streams; and most of the estimates made by those interested in water-powers are evidently too great, and are of little use for our purpose. However, the remarks made by practical millers and manufacturers, the observations upon the amount of power actually in use, and upon the nature of the drainage basins, permit a rational comparison of these rivers, and in this way:

If we take the increase in ordinary low flow of the main river, from Minneapolis down to Rock Island, and deduct the discharge of the rivers whose ordinary low flow is already fixed upon, the remainder will be the ordinary low flow from the remaining drainage area between those two places. In the same way can be determined the total flow of the streams between Rock Island, Burlington, and Hannibal. Going through this process we obtain the following figures for the flow per square mile. For convenience of comparison the results obtained from the tables are inserted beside those calculated from the flow as estimated from the United States engineers' reports, although they were deduced from them. The amounts of flow of the Minnesota, Saint Croix, Chippewa, Black, Wisconsin, and Rock rivers are already determined upon, and hence deducted:

Region considered.	ORDINARY LOW FLOW PER SECOND PER SQUARE MILE.	
	U. S. reports.	Tables.
	Cubic feet.	*Cubic feet.*
Minneapolis to Rock Island..	0.358	0.281
Rock Island to Burlington...	0.229	0.248
Burlington to Hannibal.....	0.156	0.214
Minneapolis to Rock Island..	0.358	0.281
Minneapolis to Burlington...	0.304	0.267
Minneapolis to Hannibal.....	0.244	0.245

From a knowledge of the nature of the country drained by the low-flow rivers involved in the above table, and from estimates given by those using their water-power, it seems hardly probable that there is so great a decrease in the flow per square mile toward the south as is indicated in the column headed "U. S. reports." Hence, in obtaining the amounts in the column headed "Tables," we take the average flow per square mile from Minneapolis to Hannibal (exclusive of the rivers named) and alter it for each river basin according to the characteristics of that basin, taking care that the total flow from the tributaries shall approximate to the ordinary low flow as determined for Rock Island, Burlington, and Hannibal. Due account is also taken of the flow from the "brook areas". (See remarks on drainage areas.) Thus, the Cannon river, for example, has a number of lakes in its basin, and, from the power used, is considered to have an ordinary low flow of 0 29 cubic foot per second. The Root, Zumbro, etc., are fed

by many springs, and have many mills upon them; they are given 0.28 cubic foot. The Des Moines is an unsteady river like the Minnesota, and, according to the best figures we can obtain, is not entitled to more than 0.20 cubic foot.

The volumes of ordinary low flow at Rock Island, Burlington, and Hannibal, as obtained by this method, as also those estimated, as previously described, from the records of the United States engineers, are given in the following table:

Station.	ORDINARY LOW FLOW PER SECOND.	
	U. S. reports.	Tables.
	Cubic feet.	*Cubic feet.*
Rock Island	27,743	26,163
Burlington	35,000	33,700
Hannibal	38,741	38,818

The differences are due to the course pursued in lessening the *variation* in the amount of flow per square mile, and the effect is shown in the table of flow per square mile just given. In the column headed "Tables" the extremes more nearly approach the mean than in the column headed "U. S. reports". The reasons why this is the true condition have been already set forth.

Thus we have settled upon the ordinary low flow of the tributaries from Minneapolis down to the Missouri river, with the single exception of the Illinois river. This stream, with its drainage area of over 29,000 square miles, might be expected to exert considerable influence upon the main river, but the fact is that, as regards the ordinary low flow, it is of comparatively small consequence. Major G. J. Lydecker, stationed at Chicago, who is in charge of the Illinois river, has very kindly communicated his views regarding its flow. He states that when the river is at its lowest stage in an average year the discharge is substantially 1,750 cubic feet per second. "During the general low-water season the stage of the river will fluctuate from week to week, rising after heavy rains and resuming its ordinary low stage after their effects have passed away." "The average flow during this season is probably about 2,000 cubic feet per second," or 0.069 cubic foot per second per square mile. This estimate, which seems an exceedingly low one, is apparently based on a gauging made at Spar island, 35 miles above the mouth, on September 16, 1879. The river was then at an extreme low stage, and gave a flow of 1,566 cubic feet per second.

The Illinois basin is, as Major Lydecker remarks in his letter, flat and mainly prairie, much reducing the ordinary low flow, but the estimate of the flow at a similar stage at the upper waters fully equals, if it does not exceed 2,000 cubic feet per second, and it seems hardly probable that the lower tributaries do no more than supply the evaporation. With due respect for Major Lydecker's estimate, it seems improbable that it is sufficiently large. It is employed, as stated by himself, only as an approximation.

Tributaries above the Minnesota.—Having gained an idea of the ordinary low flow per square mile from the several varieties of land to be found in the Upper Mississippi basin—from wooded, swampy country to dry prairie—we are in a condition to retrace our steps and estimate the ordinary low flow of the tributaries that enter above Minneapolis.

Taking the ordinary low flow past Minneapolis as 6,017 cubic feet per second, gives an average flow per square mile for the drainage area above of 0.307 cubic foot per second. The tributaries above Minneapolis are some of them prairie streams, some drain woodland, and many of them have a great number of swamps and lakes within their basins. The problem is much the same as before: to distribute the total flow of the river among the tributaries, according to the physical characteristics of their basins, checking the results by the gaugings at different points along the main stream. This has been done, and the results are given in the tables. As already stated, they are believed to be less than the true amounts rather than greater.

Effects of the lakes.—Those streams which drain prairie regions have many lakes tributary to them, and hence the flow per square mile is raised to 0.29 or 0.30 cubic foot per second. The other rivers are very similar in the characteristics of their basins to streams like the Saint Croix and Chippewa, and hence their flow per square mile is estimated to be from 0.33 to 0.37 cubic foot per second. In the Leech Lake basin especially there is great natural storage capacity, and it might be thought that the flow per square mile would be greater than for streams like the Saint Croix; but it must be remembered that the rainfall is only about 25 inches in the one case, while it is nearly 10 inches greater in the other. Also the low flow per square mile is usually larger, other things being equal, from a large than from a small drainage area.

The culminating point of effect from the remarkable system of natural reservoirs is at the mouth of the Leech Lake river, as shown by the following selections from the table. Below this the prairie influence gradually gains the ascendency. This is shown strikingly by the curve of ordinary low flow:

Station.	Ordinary low flow per second per square mile of drainage area above station.
	Cubic feet.
Head of Cass lake	0.334
Outlet of lake Winnibigoshish	0.337
Mouth of Leech Lake river	0.351
Grand Rapids	0.349
Brainerd	0.323
Sauk Rapids	0.312
Minneapolis	0.307

Table of flow per square mile for various kinds of country.—From the estimates we have been making in the preceding pages, and which are inserted in the two tables, the following conclusions are reached concerning the ordinary low flow (as previously defined) per square mile from the various kinds of topography met with in the upper Mississippi basin. The figures are derived from drainage areas of from 1,000 to about 15,000 square miles, and refer to the flow of all the months except from December through to March:

Nature of country.	Annual precipitation.	Ordinary low flow per second per square mile of drainage area.
	Inches.	*Cubic feet.*
Swamp and woodland with large lakes	25 to 35	0.37 to 0.40
Swamp and woodland		0.30 to 0.37
Prairie and lakes		0.28 to 0.34
Prairie and woodland		0.28 to 0.34
Rolling prairie with scattered groves and springs in the river bluffs		0.20 to 0.30
True prairie streams		0.06 to 0.20

AVERAGE FLOW.

The term *average flow* has already been defined, and its importance to the water-power interests has been pointed out. It will be readily seen that it is very difficult, if not impossible, to determine the average discharge of a stream unless daily gaugings have been made. The subject is more uncertain than is the case with the ordinary low flow, because even the records of the stages of the river which can be relied upon to a certain extent in estimating the latter, cannot be considered to give a sufficiently close approximation for the former. On this account the estimates of average flow for the Mississippi basin are not so closely based upon actual records as are those of the ordinary low flow; enough daily gaugings are in our possession, however, to make an approximation possible. The same course is pursued as in determining the ordinary low flow. The gaugings upon the main streams are used to check the summation of the estimates for the tributaries, and these estimates are made in accordance with the physical conditions of the several drainage basins.

The report of Humphreys and Abbott gives valuable gaugings and calculations of flow for the lower river. Upon the upper portion of the river the only gaugings obtainable, at the time of making the calculations, which gave daily readings, were those made under the direction of Major Charles J. Allen at and above Saint Paul. We are enabled to ascertain the average stage at Rock Island and at one or two other points, but generally the average stage gives a very uncertain idea of the actual average flow, and cannot be relied upon. As far down as Minneapolis the results may be considered a rather close approximation, with data derived from the work done for the proposed "reservoir system". As the actual average flow is somewhat more dependent upon the amount of rain than is the ordinary low flow, it will be estimated in terms of that quantity, as so many per cent. of the annual precipitation, instead of in terms of the flow per square mile.

Minnesota river.—Let us first deal with the Minnesota river, and get an approximate idea for streams of that character. No long continued gaugings have been made upon it.

In 1867, which was a year of high rainfall, General G. K. Warren made a large number of gaugings, from which can be obtained the average flow from June 22 to November 18. From Major Allen's report of January 16, 1881,

by comparing the records of the stations at Minneapolis and Saint Paul, can be obtained an approximation to the average flow of the Minnesota river from November 18 to April 9, 1875–'76; 1875 was a high-flow year for the Minnesota basin, judging from Major Allen's records. By combining the two we get 8,885 cubic feet per second; the average flow for a high rainfall year of about 32 inches. Assuming a direct proportion between the flow and the amount of annual precipitation, we get an average flow of 7,775 cubic feet per second for a year of average precipitation (28 inches). Hence the average flow is 23 per cent. of the annual precipitation. This, of course, can only be considered a rough approximation, but it agrees well with other results.

The river above the Minnesota.—Next we will consider the streams above Minneapolis. The daily gaugings of the flow made at Saint Paul, Minneapolis, Sauk Rapids, and Brainerd, have already been employed in estimating the ordinary low flow. They were conducted during the year 1875, mostly from March or April through the summer into November. At Minneapolis daily records of the stage were kept throughout the entire year. Fortunately for our purpose, 1875 was in this region a year of about average precipitation. To determine the average flow of the year it is necessary to know what it is during the three months, more or less, when no records were kept.

Mr. Joseph P. Frizell, Major Allen's chief assistant, is one of the most experienced engineers in his specialty in the country, and his careful study of the upper Mississippi makes his opinion concerning it of great value. In preparing the tables for Major Allen's report he estimates the average flow at the several stations during the winter season and inserts it.

The policy at Major Allen's office appears to have been throughout to make low estimates, and hence Mr. Frizell's figures probably err, if at all, on the safe side. For the period in question he assumes an average flow of 5,585 cubic feet per second at Saint Paul from November 18 to April 9; 5,000 cubic feet per second at Minneapolis from November 17 to April 1; 5,363 cubic feet per second at Sauk Rapids from November 1 to April 18; and 2,715 cubic feet per second at Brainerd from November 18 to April 6.

These figures we will assume as correct, and use the tables in Major Allen's report to determine the average flow of the year. The average flow of the year was: At Saint Paul, 25,145 cubic feet; at Minneapolis, 13,558 cubic feet; at Sauk Rapids, 9,797 cubic feet, and at Brainerd, 5,656 cubic feet per second. The flow at Saint Paul is evidently much in excess of what it would be for an average year, because of high water in the Minnesota river; hence it is discarded in our calculations. Comparison of the other estimates of flow with the average yearly precipitation gives these results:

(For convenience of comparison the results obtained from the two tables of the Mississippi are inserted beside those calculated from the flow as taken from Major Allen's report, although derived from them.)

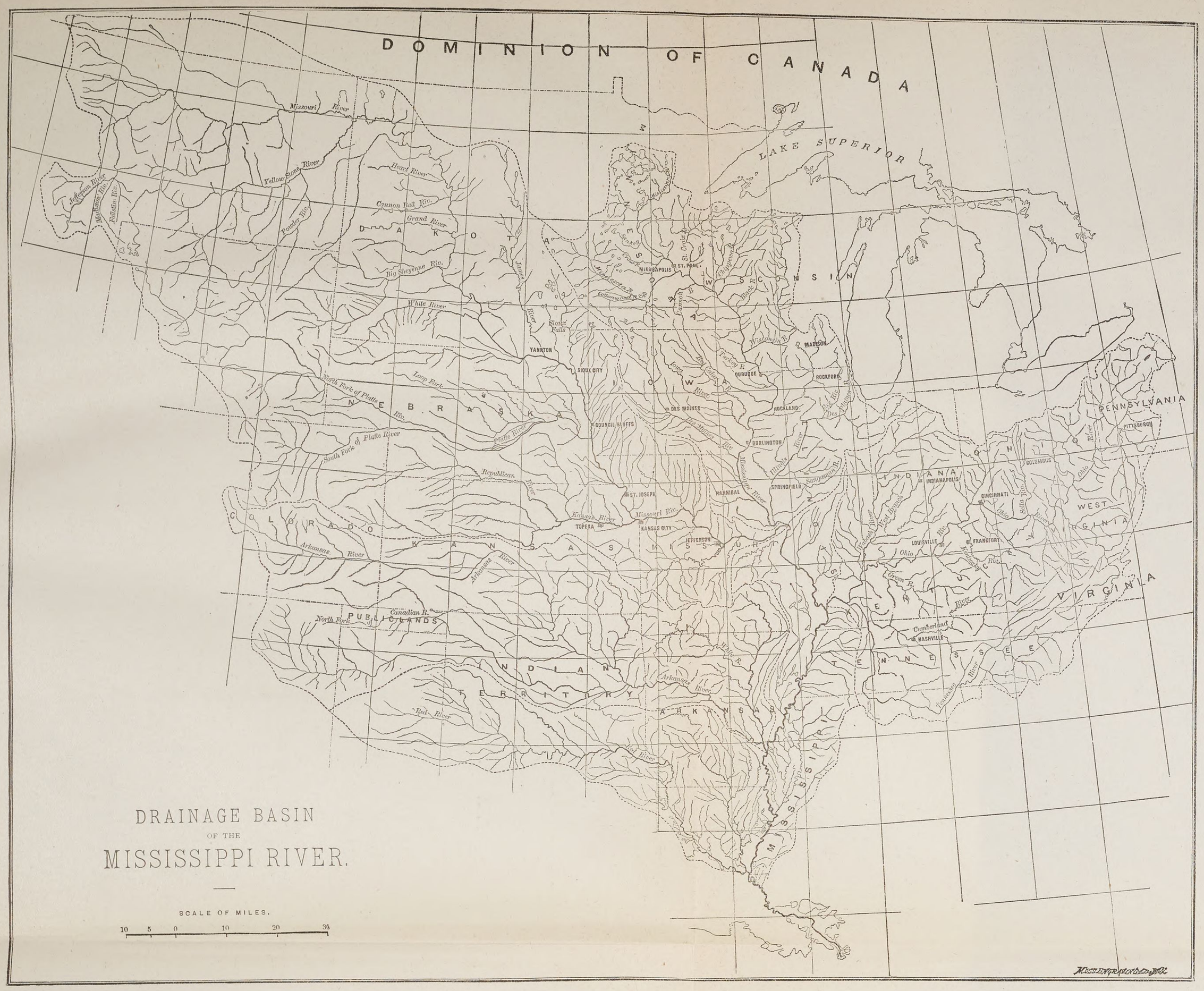
Region considered.	RATIO OF AVERAGE FLOW TO ANNUAL PRECIPITATION.	
	U. S. reports.	Tables.
	Per cent.	*Per cent.*
Minneapolis to Sauk Rapids	28.71	30.68
Sauk Rapids to Brainerd	34.84	34.27
Brainerd to source	43.61	39.40
Above Minneapolis	35.74	34.70
Above Sauk Rapids	39.46	36.90
Above Brainerd	43.61	39.40

In the same way as in the case of the ordinary low flow, the ratio gradually increases toward the source. This is undoubtedly due to the change in the nature of the country from prairie to tamarack and cedar swamps and woodland.

While the large number of lakes exerts the great effect already demonstrated upon the ordinary low flow, it cannot be considered to be so instrumental in increasing the ratio of average flow. The evaporation from their surfaces nearly, if not quite, equals the annual precipitation upon them. We are to look rather to the nature of the soil and growth for an explanation of the increase in ratio shown in the table.

The swampy, wooded character of the country about the sources of the Mississippi, and the sandy, "drift" nature of the soil are probably the chief causes of the high proportion the annual flow bears to the precipitation. In view of this fact it is thought proper to make the variation for the different river basins more gradual in the case of the average than of the ordinary low flow, as shown by a comparison of the two curves. On this account we will distribute the variation shown in the column headed "U. S. reports" more gradually between the source and Minneapolis.

As the result of a comparison of the nature of the several drainage basins, of the flow at the three stations upon the main river as given in Major Allen's report, and of the ratios of average flow to average precipitation deduced therefrom, we obtain the ratios given in the two tables of the Mississippi and the column headed "Tables" in the one just adduced. Their accuracy is not vouched for, and yet it is believed that they are not far from the truth. The probability is that they give less than the true amounts, rather than more.



DRAINAGE BASIN
OF THE
MISSISSIPPI RIVER.

SCALE OF MILES.

10 5 0 10 20 30

ROSS ENGRAVING CO. N.Y.

For convenience of comparison the following table is inserted:

Station.	AVERAGE FLOW PER SECOND.	
	U. S. reports.	Tables.
	Cubic feet.	*Cubic feet.*
Brainerd	5,656	5,101
Sauk Rapids	9,797	9,174
Minneapolis	13,558	13,193

The average flow of the Minnesota river has been determined. This, taking account of the intervening "brook area" (see remarks on "drainage areas"), makes the average flow past Saint Paul 20,925 cubic feet per second. We have yet to consider the river below.

The river below the Minnesota—Statement of the nature of the problem.—In order to understand clearly the conditions, it is best to say at the outset that we have no actual gaugings upon the river to help us between Saint Paul and Columbus, below the mouth of the Ohio; neither do series of gaugings upon the side streams give us much clue to their actual average discharge. The best we can do is to apply our knowledge of the ratio of flow for various kinds of land surface to the drainage basins of these tributaries, and make the total foot up to the average flow of the Mississippi as ascertained at Columbus, Kentucky. In this we do not have to rely upon published ratios of flow to precipitation, deduced for other streams of perhaps far different character.

The ratios just determined for the tributaries above Saint Paul (see tables) can be safely used as approximations for streams draining country of a similar nature, and the estimates of Humphreys and Abbot for the average discharge give a clue to the value for low-ratio streams. Their estimate gives an average of 15.9 per cent. of the precipitation, entering the Mississippi from the Arkansas basin (including the White river). This is very nearly the general percentage assumed in the West for the low-ratio prairie streams of the Mississippi basin.

The ratios obtained for the Minnesota and the first three or four tributaries above, serve as guides in making estimates for streams draining country of an intermediate nature. The percentages found for the high-ratio rivers in the upper waters can be reasonably applied to the very similar basins of the Saint Croix, Chippewa, Wisconsin, and other streams.

Thus we are enabled by comparison to run through the complete list of tributaries down to the Ohio, with apparently reasonable claims of being approximately correct, especially as the sum total agrees with the gaugings made on the lower Mississippi. The effects of change in climate on passing south, if it has any effect upon the average flow, are unnoticeable compared with the uncertainties arising from scarcity of gaugings.

The basins of the Saint Croix, Chippewa, Black, and Wisconsin are wooded, and, particularly in the cases of the largest three, abound in tamarack and cedar swamps at their upper portions. Nearer the mouths of the rivers the basins are more open, especially on the Wisconsin; but, nevertheless, these streams stand high among the high-ratio rivers of the upper Mississippi. They are given ratios varying from 35 to 37 per cent.

The intervening streams drain largely prairie interspersed with groves, and as they are said to be fed by many bluff springs, they are given a ratio of from 26 to 28 per cent., falling to 24 per cent. for the Iowa river, which has considerable prairie land like that drained by the Minnesota.

For the Rock river a high ratio of 35 per cent. is used, because of the remarks of engineers regarding it and the swampy nature of much of the surface drained; it cannot be classed as a prairie stream. The Des Moines has a large amount of uncultivated prairie within its basin, giving a small return for the rain granted to it. It is not thought to have a ratio of not more than 20 per cent.

Considering the character of the large tributaries at the upper portion of the Illinois river, where one stream is much like the Rock river in nature, while another drains extensive swamp and woodland, 24 per cent. is thought to be not too high a ratio to assume for it, although extensive tracts of level prairie are tributary to its flow.

Missouri river.—For the Missouri nothing better can be done than to compare it with the Arkansas, the method used by Humphreys and Abbot.

Estimates (furnished to Mr. Dwight Porter by Major Suter, and kindly placed at my disposal) of the average monthly flow for 1879, give an average flow for that year of 74,047 cubic feet per second, but this, from an inspection of the monthly averages, was so evidently a year of low total discharge as to be of little value for our purpose.

The Missouri basin is very similar in character and in proportion of prairie and mountain to the basin of the Arkansas. The distribution of the rainfall is also much the same in character—light at the sources and increasing toward the mouth, although the average is higher for the Arkansas than for the Missouri. Hence we assume a ratio of 16 per cent. for the Missouri. This gives an average discharge of 121,900 cubic feet per second.

From the Missouri down to the Ohio the ratio is assumed to be 26 per cent. after a comparison with the country drained by the semi-prairie streams of the upper Mississippi.

Ohio river.—For the Ohio no gaugings exist, so far as known, which can aid us in determining the actual average discharge. The method used by Humphreys and Abbot was to assume the ratio of flow to precipitation equal in the cases of the Ohio and the upper Mississippi, because of a certain similarity in the physical characters of their basins. Hence they employed a ratio of 24 per cent. for the Ohio. If we made the same supposition we would use 27.5 per cent., the ratio estimated for the upper Mississippi. (See table of main river).

Now, from one-quarter to one-third of the Ohio basin is mountainous and clothed with timber; by far the greater portion of the remaining area, lying in Kentucky and Tennessee, is rolling, broken, or even hilly country, very largely covered with woods. To the north, in Ohio and Indiana, the country is mostly rolling land, with the river channels generally cut deep in the surface and considerable amounts of timber interspersed with prairie. Much of the land is also cultivated.

The ratio for mountain streams in the eastern states is found to range from 50 to 70 per cent., or even more in extreme cases. We have already found the ratio for regions in the Mississippi valley intermediate between prairie and wooded country to be from 25 to 30 per cent.

In view of these facts it is thought that 30 per cent. is a closer estimate for the Ohio basin than 24 per cent., and this is adopted. This ratio makes the average discharge 203,846 cubic feet per second.

The flow given in Humphreys and Abbot's report is 158,000 cubic feet. Their estimate of the average annual precipitation upon the basin is 41.5 inches. Using the Smithsonian publications, we estimate it to be 43.1 inches. The reason for using a higher ratio has just been shown, and, considering all the circumstances, it seems more nearly correct.

Average flow past Columbus—a check upon the calculations.—Thus the average flow from the Mississippi basin is estimated down to Columbus, and the table gives a flow past that place of 456,538 cubic feet per second.

Humphreys and Abbot estimate, by gaugings, the average discharge past Columbus for the year from December 1, 1857, to December 1, 1858, to have been 621,002 cubic feet per second.

The year of 1858 was one of almost universal heavy rainfall upon the Mississippi basin, and four great floods occurred, of which we get this description from Humphreys and Abbot's report:

The first, caused mainly by the Ohio, occurred in December, 1857; the rivers below were at a low stage.

The second occurred in March and April, 1858, and was caused by a general swelling of the lower tributaries of the Missouri, upper Mississippi, and Ohio. During this flood the rivers below the Ohio were high, especially the Arkansas.

The third flood was caused in the latter part of April, 1858, by heavy rains on the lower tributaries of the Ohio (the Tennessee river was unusually high), Missouri, and upper Mississippi. All the tributaries below the Ohio were then comparatively low.

The fourth, an almost unprecedented flood, took place in June, 1858. The Ohio, Missouri, and upper Mississippi were enormously swollen.

Quoting from Humphreys and Abbot: "With the Ohio and Mississippi both in full flood, the torrent which poured into the alluvial region by the river itself, and through the swamps above Columbus, was immensely greater than in any of the earlier rises of the year, and second to none of which we have records."

"The upland tributaries below the Ohio were all low during this rise" although heavy rains took place in the Saint Francis and the White River swamps.

On page 130 of their report (edition of 1876), Humphreys and Abbot state the total discharge of the Mississippi from November, 1857, to October, 1858, to have been 26,000,000,000,000 cubic feet, not including the discharge of the Red river. On the same page they give as the average for 33 years, 19,400,000,000,000 cubic feet. Hence the average is only 74.615 per cent. of the discharge above the mouth of the Red river during the year of 1858. As by far the greater part of the high floods of 1858 entered the river above Columbus, it is fair to suppose that this ratio between the average flow and the average flow for 1858 would hold good at that place, being, if anything, slightly diminished, because the floods of 1858 were relatively so much greater from the area above Columbus than from the total area above the Red river.

It has already been stated that the average discharge at Columbus from December, 1857, to December, 1858 was 621,002 cubic feet per second. Applying the ratio of 74.615 per cent. to this amount gives 463,361 cubic feet per second. The table of the main river, computed as has been described, from the best data at hand concerning the flow of the rivers above Columbus, gives an average flow past that place of 456,538 cubic feet per second, less than the amount just given by 6,823 cubic feet per second, and equal to 73.516 per cent. of the average flow for 1858. This is a reduction of 1.099 per cent. on the ratio just given, and, as previously stated, there probably should be a slight reduction of this kind, how much we do not know.

The above seems a pretty good indication that the estimates already presented are not far from the truth, in the aggregate at least. We have now to consider the Mississippi below Columbus.

The river below Columbus.—The chief tributaries below Columbus are the Arkansas and Red rivers, then the Saint Francis and Yazoo rivers, and finally streams like the Forked Deer, Big Hatchee, Big Black, and others.

Humphreys and Abbot found the total discharge of the Arkansas (including the White river) for 1858 to average 74,126 cubic feet per second. They take the average flow for an *average* year to be 63,000 cubic feet per second.

This agrees well with the results just deduced, as 63,000 is 85 per cent. of 74,126, and 85 per cent. is much greater than 74.6 per cent. The ratio should be greater than for the entire Mississippi basin, because the floods of 1858 were much less relatively upon the Arkansas than on the rivers above.

Red river.—Humphreys and Abbot estimated the average discharge of the Red river in the following manner.

It must be understood that at the time of writing their report there were three bayous tapping the Mississippi below the Red river. Of these the average flow in cubic feet per second was quite closely ascertained, as follows:

Atchafalaya bayou	50,000
Bayou Plaquemine	5,000
Bayou La Fourche	2,000
Total	57,000

This amount was abstracted from the Mississippi below the Red river.

The averages of 23 years of estimates at Natchez and of 10 years at Carrollton, near New Orleans, give a difference of only 31,000,000,000 cubic feet per year, or about 900 cubic feet per second in favor of the discharge past Natchez. Now, as the Red river enters between Natchez and Carrollton, and the bayous start between those places, the average discharge of the Red river must practically equal the average outflow through the bayous, viz., 57,000 cubic feet per second.

It will be noticed that in this calculation no account has been taken of the discharge from the Homochitto river and the "brook area", tributary to the Mississippi between Natchez and Carrollton. This can be assumed from the tables to be about 7,000 cubic feet per second. Deducting this, we take 50,000 cubic feet per second as the *approximate* average discharge of the Red river.

Yazoo, Saint Francis, etc.—We have now these results:

	Cubic feet per second.
Average flow above the Red river	615,167
Average flow past Columbus	456,538
Difference	158,629
Average discharge from Arkansas basin	63,000
Remainder	95,629

This remainder is the average flow from the Yazoo, Saint Francis, Forked Deer, and other streams, entering between Columbus and the Red river. The average precipitation upon the area represented by these streams is 156,460 cubic feet per second, and we are forced to the conclusion that the ratio of average flow to average precipitation for them is about 61.12 per cent. Humphreys and Abbot estimate the ratio to be 96 per cent., but they use throughout the data collected for 1858, instead of average amounts, and it hardly seems that their use would give as close average results as that of data for an average year.

Cause of the high ratio.—The reason for this high ratio of 61 per cent. lies apparently in the nature of the country. The region is very largely what is there called river-bottoms, consisting of immense tracts of swamp and low land, covered with an almost semi-tropical vegetation. The water soaks into the ground, stands in deep pools and lagoons, and is protected by the dense covering of foliage, so that the evaporation is comparatively small, although moisture is absorbed by the growth. On the uplands, which are rolling and broken, the tendency is, as stated by Humphreys and Abbot, for the rains to rapidly drain off and find the protection of the swamps.

Many of the ridges of the uplands are also sandy and gravelly in nature, and into them the rains quickly sink away from the effects of sun and vegetation, to appear as springs in the running brooks. Another point of importance is that most of the rainfall of the year occurs in winter, when the average temperature, according to the Smithsonian charts, is only from 40 to 50 degrees, while in summer it varies from 75 to 80 degrees.

Again, the evaporation, even of summer, can hardly be so great as might be supposed from the high temperature, as compared with that in more northern portions of the Mississippi basin, for this reason: Being near the Gulf coast, and traversed very largely by winds directly from that warm body of water, the tendency is for the air to be constantly near the saturation point for the existing temperature (this is indicated by the comparatively uniform distribution of rainfall through the season), and hence the evaporation goes on more slowly than if the atmosphere were dry.

From the report of Humphreys and Abbot (page 299, edition of 1876) are obtained the following figures:

Drainage basin.	AREA IN SQUARE MILES.	
	Bottom-lands.	Uplands.
Yazoo	7,110	6,740
Saint Francis	6,900	3,600
Area in Tennessee and Kentucky	750	9,500
Total	14,760	19,840

The bottoms are about 75 per cent. of the uplands in extent. The average ratio of flow to rainfall for the entire region is 61.12 per cent. The ratio for the upland region is thought to be, from comparison, not higher than 40 or 50 per cent., but no exact data can be obtained. If it is 40 per cent., then the ratio for the bottom-lands is 90 per cent.; if 50 per cent., then the ratio for the bottom-lands is 76 per cent.; if 45 per cent., then the ratio for the bottom-lands is 83 per cent.

The endeavor has been made to assign an average ratio for each river basin in accordance with its proportion of upland and bottom-land, and the probable ratio for its upland.

The Forked Deer, Big Hatchee, and Wolf River basins are given a ratio of 45 per cent. They are very largely highland. The Saint Francis and the Yazoo, with such a large proportion of lowland, are given a ratio of 70 per cent.; and so on, due account being taken of the flow from the intermediate small areas not included in the river basins.

Flow of the main river at the mouth of Red river.—After footing up the total amount we find the average flow of the Mississippi, above the mouth of the Red river, to be 614,472 cubic feet per second, only 695 cubic feet per second or 0.001 per cent. less than the average flow determined by Humphreys and Abbot from 33 years of river gaugings.

Table of average-flow ratios for various kinds of country.—From a comparison of the various physical characters of different portions of the Mississippi basin, with the ratios of average flow to average precipitation, as contained in the tables we have just deduced, can be obtained the following approximate ratios for the different kinds of topography and climate met with in the central portion of the United States.

Table of ratios of average flow to average precipitation.

Character of region drained.		Average temperature.		Time of heaviest precipitation.	Ratio of average yearly flow to average annual precipitation.
		Three summer months.	Three winter months.		
		Degrees.	*Degrees.*		*Per cent.*
Rather level woodland, many wooded swamps, many lakes	1	60 to 64	4 to 12	Summer and spring	35 to 40
Sandy ridges, undulating woodland and prairie, a few swamps and lakes, largely clay soil	2	64 to 68	8 to 16	....do	30 to 40
Undulating woodland and prairie, largely uncultivated, few swamps, no lakes, largely clay soil	3	64 to 68	8 to 16	....do	27 to 35
Flat to rolling prairie, partly cultivated, scattered woodland, largely clay soil	4	60 to 70	12 to 20	....do	20 to 30
Flat to rolling prairie, very largely uncultivated	5	68 to 72	16 to 26	... do	15 to 20
Extreme cases of the last division	6	68 to 72	16 to 26	....do	10 or less (?)
Combination of six parts of rolling upland (clayey or sandy soil), with four parts of swampy, densely-grown bottom-land, met with on the lower Mississippi.	7	75 to 80	40 to 50	Winter and spring	61
Average of the entire Mississippi basin	8	73	28	Summer and spring	24

It is out of the question to attempt to bring the ratios down to closer limits with the data at hand, but it is believed that the percentages just given include within their limits the correct amounts.

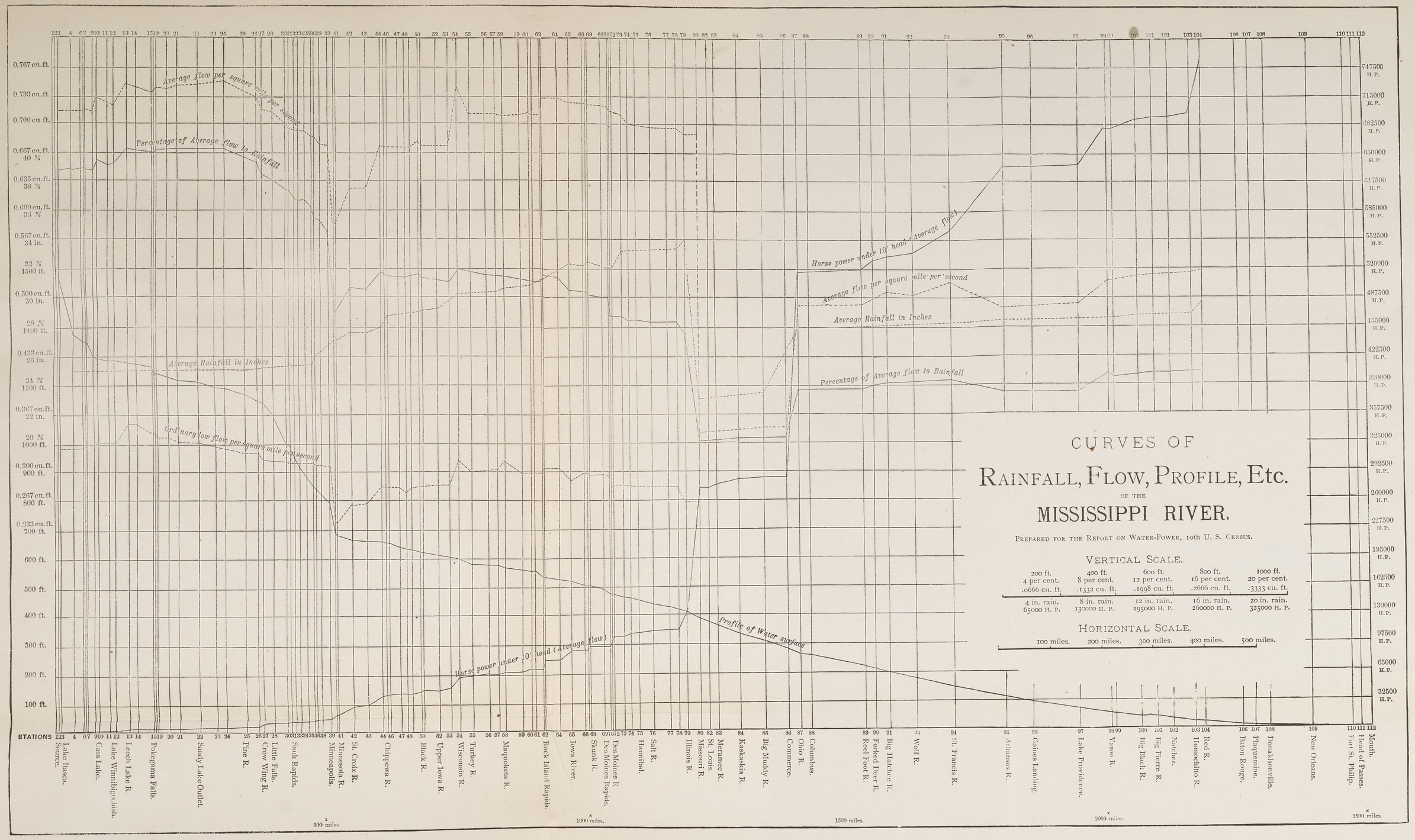
Average-flow ratio a complex problem.—However, such an immense number of influences bear upon this question of average-flow ratio as to make it an extremely uncertain one. Certainly, not until long-continued and precise records have been made of the flow of the streams, the rainfall, the direction of the winds, the temperature (*a*), the hygrometric state of the atmosphere, and the times of occurrence of these several conditions, can accurate ideas be formed of their effects upon the flow. That they have great influence is undoubted. The ratio for the same region will often vary many per cent. in successive years.

Then, in comparing different regions, the problem is immensely more complicated; there must be brought into consideration the nature of the country—whether the land is wooded or open, whether low and swampy or hilly and well drained, whether cultivated or not. If lakes occur, the effects of evaporation from their surfaces must be considered. The nature of the soil and underlying rock strata should also be taken into account; whether the surface is rocky or the soil is stiff, impervious clay, over which the water runs rapidly, or whether it consists of light sand and gravel, into which moisture rapidly sinks. If the water does find its way below the surface, is the condition of the underlying strata such that it is carried deep into the earth, to appear in some far distant artesian well, or does it merely spring out from the bases of the ridges to swell the neighboring streams?

It may be easily seen that to grasp the subject fully and master its details would require well nigh supernatural powers. No one can pretend to say what the precise flow of water from a given area will be.

All these various influences occur in the Mississippi basin—mountain and plain, woodland and prairie, lake, swamp and arid land, sandy soil, deep-seated drainage through rock strata, and the infinitude of meteorological conditions, all exist. Yet, in spite of them all, an approximation can be made, and this has been attempted on the preceding pages.

a In this connection it must be remembered that the amounts lost by direct evaporation and absorbed by vegetable growth do not have the same ratio for different years as the amounts of precipitation. The rainfall of one year may be double that of the preceding one, while the loss by evaporation may remain about the same.


CURVES OF
RAINFALL, FLOW, PROFILE, Etc.
OF THE
MISSISSIPPI RIVER.
PREPARED FOR THE REPORT ON WATER-POWER, 10th U. S. CENSUS.
VERTICAL SCALE.
200 ft. 4 per cent. .0666 cu. ft. 4 in. rain. 65000 H. P.
400 ft. 8 per cent. .1332 cu. ft. 8 in. rain. 130000 H. P.
600 ft. 12 per cent. .1998 cu. ft. 12 in. rain. 195000 H. P.
800 ft. 16 per cent. .2666 cu. ft. 16 in. rain. 260000 H. P.
1000 ft. 20 per cent. .3333 cu. ft. 20 in. rain. 325000 H. P.
HORIZONTAL SCALE.
100 miles. 200 miles. 300 miles. 400 miles. 500 miles.
Average flow per square mile per second
Percentage of Average flow to Rainfall
Average Rainfall in Inches
Ordinary low flow per square mile per second
Horse power under 10' head (Average flow)
Profile of Water surface
0.767 cu. ft.
0.733 cu. ft.
0.700 cu. ft.
0.667 cu. ft. 40 %
0.635 cu. ft. 38 %
0.600 cu. ft. 36 %
0.567 cu. ft. 34 in.
32 % 1500 ft.
0.500 cu. ft. 30 in.
28 % 1400 ft.
0.433 cu. ft. 26 in.
24 % 1200 ft.
0.367 cu. ft. 22 in.
20 % 1000 ft.
0.300 cu. ft. 900 ft.
0.267 cu. ft. 800 ft.
0.233 cu. ft. 700 ft.
600 ft.
500 ft.
400 ft.
300 ft.
200 ft.
100 ft.
747500 H.P.
715000 H.P.
682500 H.P.
650000 H.P.
617500 H.P.
585000 H.P.
552500 H.P.
520000 H.P.
487500 H.P.
455000 H.P.
422500 H.P.
390000 H.P.
357500 H.P.
325000 H.P.
292500 H.P.
260000 H.P.
227500 H.P.
195000 H.P.
162500 H.P.
130000 H.P.
97500 H.P.
65000 H.P.
32500 H.P.
STATIONS
Lake Itasca. Source.
Cass Lake.
Lake Winnibigoshish.
Leech Lake R.
Pokegama Falls.
Sandy Lake Outlet.
Pine R.
Little Falls.
Crow Wing R.
Sauk Rapids.
Minneapolis.
Minnesota R.
St. Croix R.
Chippewa R.
Black R.
Upper Iowa R.
Wisconsin R.
Turkey R.
Maquoketa R.
Rock Island Rapids.
Iowa River.
Skunk R.
Des Moines Rapids.
Des Moines R.
Hannibal.
Salt R.
Illinois R.
Missouri R.
St. Louis.
Meramec R.
Kaskaskia R.
Big Muddy R.
Commerce.
Ohio R.
Columbus.
Reed Foot R.
Forked Deer R.
Big Hatchee R.
Wolf R.
St. Francis R.
Arkansas R.
Gaines Landing.
Lake Providence.
Yazoo R.
Big Black R.
Big Pierre R.
Natchez.
Homochitto R.
Red R.
Baton Rouge.
Plaquemine.
Donaldsonville.
New Orleans.
Mouth.
Head of Passes.
Fort St. Philip.
500 miles.
1000 miles.
1500 miles.
2000 miles
2500 miles.

Variation in ratios.—The following data are inserted as illustrating the immense variation in the ratio of flow to rainfall for various sections. The yearly variation for the same district cannot be better shown than in Mr. Joseph P. Frizell's paper, contained in Major Allen's valuable report to the chief of engineers, dated December 28, 1878. A portion of it is here quoted in full:

Observations have been made for some twenty-five years past at lake Cochituate, from which the city of Boston has, until recently, derived its supply of water, of the rainfall on and discharge from a district some 19 square miles in area. I am in possession of the results from 1852 to 1875, inclusive, a period of twenty-four years. The average flow is about 45 per cent. of the rainfall, which has averaged some 50 inches. To show the extreme uncertainty of these results, it may be mentioned that in 1857 the rainfall was 63.1 inches, 74 per cent. of which was represented by the discharge. In 1866 the rainfall was nearly the same, viz, 62.3 inches, only 25 per cent. of which appeared in the discharge. The latter was the lowest percentage shown during the twenty-four years. The highest was in 1859, being 78 per cent. on a rainfall of 49 inches. The highest rainfall of the period was 69 inches in 1863; the lowest, 35, in 1855. In other words, the variations in the rainfall are as 2 to 1. The variations in the discharge with the same rainfall are as 3 to 1. In 1857 the aggregate discharge was equivalent to 47 inches on the entire drainage-basin. In 1871 it was 15 inches.

From measurements of the Sudbury river, Massachusetts, made for six years by Alphonse Fteley, and published in the *Transactions of the American Society of Civil Engineers* for July, 1881, are obtained these figures: The drainage area is 77.76 square miles; the variation in the annual rainfall was from 38 to 58 inches, and the ratio of discharge to rainfall from 32.71 to 57.90 per cent., the average being 47.56 per cent.

Regarding the variation for various sections, the following data are taken from Mr. J. T. Fanning's *Treatise on Water-Supply Engineering.*

Ratio of average flow to rainfall for average drainage areas:	Per cent.
Mountain slopes or steep, rocky hills	80 to 90
Wooded, swampy lands	60 to 80
Undulating pasture and woodland	50 to 70
Flat cultivated land and prairie	45 to 60

It does not seem possible from the results we have reached that Mr. Fanning's estimate for prairie can be applied to that character of land in the Mississippi basin. From his remarks it is inferred that the figures given above are for an average precipitation of about 40 inches per year, and, as before remarked, the variation in loss from evaporation, etc., does not have the same ratio as the variation in rainfall. To this, perhaps, is partly due the difference.

From several sources these percentages are collected:

	Per cent.
Connecticut River basin	63
Concord River basin, Massachusetts	41
Croton basin, New York	57.5
West branch of Croton basin	63
Lake Cochituate basin, Massachusetts	45

The last two basins are each about 20 square miles in extent.

From the report of Humphreys and Abbot (page 295, revised edition) is obtained the result, that for moorland, with 60 or 70 inches of annual precipitation, the ratio of average flow to precipitation for an area of from 2 to 7 square miles ranges from 60 to 80 per cent.

Horse-power.—The columns giving the theoretical horse-power under an assumed head of 10 feet are inserted because of the idea they will give of the power available on the different streams, supposing a fall of water to be available. Many of the tributaries have such fall available comparatively near their mouths, and there are a number of points on the upper waters of the main stream where power could easily be utilized. It is, of course, a simple matter to determine the power under any other head than 10 feet by the mere application of direct ratio. Although there is no available power on the lower river the columns have been filled out as a matter of interest merely.

Description of the curve sheet.—In order better to illustrate the prominent features of the hydrology of the Mississippi basin the accompanying diagram has been constructed from the data given in the table. A horizontal base line was drawn representing the channel of the main river, and the stations plotted upon it from source to mouth proportionally to their distances. From these stations were drawn vertical ordinates, and on these ordinates, starting from the base line as zero, were laid off the proper distances for the different curves ascertained from the table and the scale used. The points thus obtained were connected by straight lines and the curves constructed. The lengths of the ordinates to the curves from the different stations have the same ratios to each other as the rainfall, flow, percentages, etc., for the total areas above those stations.

Profile of river.—Glancing at the profile of the water-surface this is noticed: the rapid fall is all above the Minnesota river. In this region occur the rapids over hard granite which has resisted the tendency to wear down the bed to a uniform slope, and also the falls of Saint Anthony.

Below the latter, as described in the remarks on the geology, the river runs, with two exceptions, in a soft bed of drift, which has filled up its ancient channel. Consequently, in the distance from Saint Anthony falls to the

mouth, the slope is comparatively uniform and obeys approximately the tendency to form a parabolic profile, as may be observed by a glance along the plane of the diagram. The principal exception to this is caused by the rock barriers at Rock Island and at the Des Moines rapids; they occasion a rise in the profile.

Curve of annual precipitation.—The curve of average annual precipitation above the different stations, called, for simplicity, the "rainfall curve", shows a gradual rise from a little above the Minnesota river to the Illinois, then a sudden fall of nearly 11 inches rainfall to the Missouri, a rise of about half that amount to the Ohio, and then a gradual rise to the mouth.

Curves of flow and percentage to rainfall.—The curves of ordinary low flow per square mile, average flow per square mile, and percentage of average flow to rainfall can best be discussed together. They naturally have a general similarity. Above the Minnesota river, where the amount of precipitation does not greatly change, the last two of these three curves correspond very closely.

The curve of ordinary low flow has its culminating point at the mouth of Leech Lake river, which represents the point of maximum storage capacity. Then it falls off gradually to the Minnesota river. The curve of average flow is likewise highest above the Minnesota river, but its culminating point is between the Willow River and Rice River stations, Nos. 23 and 24, although nearly as high opposite the mouth of Leech Lake river, No. 13.

As has been previously remarked, the average flow is not so dependent upon the amount of natural storage afforded by the lakes, and hence the difference from the ordinary low-flow curve. The ordinary low flow is from one-third to one-half the average flow for the entire length of the upper Mississippi.

All three curves take a sudden fall at the Minnesota river (a prairie stream) and then rise, owing to the Saint Croix, Chippewa, and Wisconsin rivers, all of them high-flow streams. The influence of each is shown.

The ordinary low-flow and average-flow curves have their culminating point, for the region below the Minnesota, at the Wisconsin river. From the Wisconsin river there is a general fall in both curves to the foot of the upper Mississippi. There the ordinary low-flow curve ceases, but the average flow and percentage curves fall very greatly, on account of the Missouri river. They then rise slightly to the Ohio river, whereupon they take a sudden leap upward, owing to that river. From the Ohio river the general direction is upward to the mouth of the Mississippi. The influence of the Arkansas river (a low-flow stream) is shown in the fall it causes in both curves. At the same time the influence of the high-flow streams like the Saint Francis, Yazoo, etc., with a ratio of flow to rainfall of 70 per cent., is shown. Notwithstanding their small drainage areas compared with the entire basin, they succeed in giving the upward tendency to the curves in this section below the Ohio river. Were it not for the Arkansas river their effect would be still more marked.

Curve of theoretical horse-power.—The curve of horse-power under an assumed head of 10 feet does not need any description. It shows the doubling of the power by the addition of the Missouri river, and then the great increase in power due to the Ohio river. The latter nearly doubles the theoretical power already existing previous to its entrance.

Deductions from diagram.—One cannot study the sheet without noticing the great influence exerted by the Missouri and the Ohio rivers.

The upper Mississippi flows along, preserving its characteristics, as indicated in the sheet. Then the Missouri enters, and for another section a new state of things prevails. The Missouri is a stream of low rainfall, low percentage, and hence low average flow. The result is a sudden and great fall in all the curves. The Ohio enters and inaugurates a new *régime* for the river down to its mouth.

The Ohio is in every respect the opposite of the Missouri; with a high rainfall, a comparatively high percentage, and hence a high average flow, it causes all the curves suddenly to rise again. Thus, there is a sharp depression in each of the curves between the ordinates representing the Missouri and the Ohio rivers.

Examining the curves between the Minnesota and the Chippewa rivers a very similar state of affairs is seen. The Minnesota bears the same relation to the Saint Croix and Chippewa that the Missouri does to the Ohio, and we find those streams carrying out in miniature the action of their larger relatives below.

DESCRIPTION OF THE WATER-POWER SITES OF THE MISSISSIPPI RIVER.

As Minnesota is a comparatively new state, and the northern part is yet almost in its native wildness, there has been no demand for water-power on the extreme headwaters of the Mississippi. The highest improved power is at Sauk Rapids, only 74 miles above Minneapolis. (*a*)

Power at the headwaters.—There are several available sites for water-powers of large magnitude, and probably near the sources a great many places where a mill might find power to turn a large amount of machinery, but no regular surveys have been made above Cass lake; and the early explorations of Schoolcraft and Nicollet did not have this subject in consideration. From their descriptions, however, and the elevations and volumes of flow given in the tables, some idea can be gained of the probable condition.

Schoolcraft describes how the river rushes down the rapids in the "Alpine passes" between lake Itasca and the mouth of the Pinniddiwin above lake Bemidji (called by him Lac Traverse). The descent averages nearly 9 feet per mile, and as there are several stretches of slack-water, the slope must be locally greater than this. The power under a head of 10 feet, at an ordinary low stage above the mouth of the Pinniddiwin river, we estimate to be 87 theoretical horse-power, enough to run a good-sized custom mill. Most of the year there would be double this power. Undoubtedly there are a number of available sites, such as are already used in the basin of the Red river of the North; whether there will ever be any demand for them is another question.

As mentioned on a previous page, these rapids, and all those down to Pokegama falls, are over accumulations of bowlders, which have prevented the river wearing its way rapidly through the drift.

From lake Bemidji to Cass lake there is a fall of about 54 feet, or 3 feet per mile; and, as Schoolcraft states that most of the descent is concentrated in the upper three-quarters of the distance in "strong rapids", there are very probably available sites there. The theoretical power under a head of 10 feet, with the ordinary low flow at the outlet of lake Bemidji, is 220 horse-power; with the average flow it is 474 horse-power. It is very probable, however, that during a high stage of the river back-water would very seriously diminish the head of water ordinarily available.

From Cass lake to Pokegama falls there is no power available; the river winds slowly along, with an average slope of 0.32 foot per mile, through a wide savanna covered with grass, wild rice, and rushes.

POKEGAMA FALLS.

These falls take their name from Pokegama lake, a body of water draining into the Mississippi about 3 miles above the falls. This lake acts as a reservoir, into which during high water the river overflows. These falls, and Grand rapids just below, are the only two rapids on the river between Cass lake and Little falls, 326 miles below, of any special importance for water-power.

Here is where the first rock in place is met. It is a red sandstone of a hard quality, dipping sharply to the southwest, and is stated by Professor N. H. Winchell to be probably the same formation that occurs at Fond du Lac, at the head of lake Superior. The latter he considers to be the most valuable for building purposes among the sandstones occurring in Minnesota. Immediately at the head of the falls, writes Schoolcraft, "is a small rocky island, covered with spruce and cedar, and dividing the channel nearly in its center."

The river rushes down a rocky channel. Above the falls it averages about 120 feet wide; at the falls it is contracted to 80 feet. The fall is 14 feet in a distance of about 500 feet, as surveyed under Major Allen. There is a good opportunity for erecting a dam at the head of the falls, and increasing the natural head of water at that point. This has been proposed in connection with the reservoir system.

On account of the level nature of the country above, a dam 30 feet high could be constructed, which would flood Pokegama lake and away back into Leech lake and lake Winnibigoshish, making an immense reservoir of that entire region. Such a plan would necessitate the building of extensive dikes along the eastern and southeastern sides of Pokegama lake, to prevent overflow into the Mississippi below, and is discouraged by those who have investigated the matter. It is possible, however, to erect such a dam at Pokegama falls. The surface of Pokegama lake is 2.6 feet above the water-surface just above the falls. A dam 7 feet high at the falls would flood an area of about 24 square miles to an average depth of 5.7 feet, without danger of breaking over the ridge to the southeast of the lake, and would give a head of 21 feet at the falls. Such a dam, in connection with several other dams above, is apparently the scheme approved of by the United States engineers.

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a If the proposed reservoir system is carried out by the United States government upon the sources of the upper Mississippi, it is doubtful how much use of power for private purposes will be allowed upon the headwaters. The policy of the government would seem to be, from past experience upon the Mississippi itself, to keep aloof, so far as possible, from all business interests in common with private individuals or corporations. Where private rights already exist from prior usage or ownership they will be respected.

Power at Pokegama falls.—The tables indicate an ordinary low flow over Pokegama falls of 1,031 cubic feet per second, giving, under a head of 10 feet, 1,170 theoretical horse-power; and an average flow of 2,183 cubic feet per second, giving, under a head of 10 feet, 2,477 theoretical horse-power. Hence the following figures:

Head of water.	THEORETICAL HORSE-POWER.	
	Ordinary low flow.	Average flow.
14 feet	1,638	3,468
21 feet	2,457	5,202

From the best information obtainable it appears that the situation admits of the utilization of this power; and it is probable that for most of the year the power available would be nearly equal to that afforded by the average flow. If the reservoirs are constructed above Pokegama falls so as completely to store all surplus, they would be capable of giving the power represented by the average flow, day and night throughout the entire year. At these powers above Brainerd, however, the shutting down of the gates of the reservoirs might at times be a source of annoyance to manufacturing interests.

GRAND RAPIDS.

The Grand rapids proper begin 3.5 miles below the foot of Pokegama falls, and in the intervening distance there is a fall of 2.9 feet. At the rapids, which can be ascended in a canoe, there is in an ordinary low stage a fall of 5 feet in a distance of about 1,500 feet. No rock in place occurs at these rapids, and the fall is stated by the engineers to be available for power. A dam, however, could not be built raising the head more than 2 feet higher without setting back the river upon the tail-races at Pokegama falls, supposing that power to be improved.

The flow at Grand rapids is practically the same as at Pokegama falls. The power with the ordinary low flow, under a head of say 6 feet is 705 theoretical horse-power; while with the average flow it is 1,492 theoretical horse-power.

THE RIVER FROM GRAND RAPIDS TO LITTLE FALLS.

In all this distance of 220 miles there is no concentrated descent worthy of mention. The average slope is 0.702 foot per mile, though locally much greater. There are several places where in low water there will be a ripple over a bowlder bed, or swift water for a half-mile or so, but they are all covered during a high stage of the river, and small steamboats, carrying supplies to lumber camps, are able to ascend them. The slope is greater below the Pine river than above, and there are one or two rapids between it and Little falls which it might be feasible to utilize by throwing a dam across the river. This, indeed, it would be possible to do above Pine river, but a dam of any considerable height would flood a long distance up stream. There is no rock in place in the river from Pokegama falls to Olmsted's bar, about 10 miles above Little falls, and the rapids are over gravel or bowlder beds.

There are seven rapids distinguished in Major Farquhar's report of February 8, 1875, as situated between Grand rapids and Pine river. They average a fall of about half a foot in 500 or 600 feet, the extremes being 0.6 foot in 290 feet, and 0.44 foot in 1,586 feet.

From Pine river to Little falls the average slope is 1.54 foot per mile, and several rapids occur much more worthy of the name than those above.

Big Eddy rapids.—Nine miles below Pine river are Big Eddy rapids. There the river falls 2.58 feet in half a mile. The average slope above to Pine river is 0.80 foot per mile. The east bank is 12 feet, and the west bank 30 feet high. Supposing it feasible to raise a head of 9 feet at this place, there would be a power of about 2,200 theoretical horse-power with the ordinary low flow, and about 5,060 horse-power with the average flow.

French rapids.—About 4 miles above Brainerd, which is on the Northern Pacific railroad, are French rapids. In a distance of 4,100 feet there is a descent of 4.6 feet. The river is there "straight and narrow, flowing between high bluffs", and the flow is slightly greater than at Big Eddy rapids during the same stage.

Olmsted's bar.—Eleven and one-half miles below the Crow Wing river is Olmsted's bar. Here is seen the first outcrop of rock in place below Pokegama falls. It is a trap dike, running out from the west bank 300 feet into the river, which is here broad and shallow. For a distance of 4 miles below the head of Olmsted's bar the average slope is 4.14 feet per mile, making a total descent of 16.6 feet. The average slope above, to the Crow Wing river, is about 0.8 foot per mile. In this stretch of 4 miles are fifteen heavily-wooded islands, overflowed during high water. The theoretical power under a 10-foot head is, with the ordinary low flow, about 3,780 horse-power, and with the average flow, 8,630 horse-power.

Conradi's shoals.—Two and one-half miles below the above stretch of 4 miles, and at an elevation about 3 feet lower than its foot, begin Conradi's shoals. Here the river widens out over a coarse gravel bank, and falls 4.74 feet in a distance of 1,500 feet.

Elk rapids.—A short distance above Little falls are Elk rapids, where in a distance of 5,100 feet the river falls 7.2 feet. Below the rapids to Little falls the average slope is 3.17 feet per mile. The flow at a given stage is essentially the same as at the mouth of the Crow Wing river.

LITTLE FALLS.

This is a rapid which occurs in the river 21 miles below the mouth of the Crow Wing, and 106 miles by river above Minneapolis. The small village of Little Falls, with 508 inhabitants, is situated on the left or east bank, a few hundred feet back from the river. About half a mile east of the town runs the railroad connecting the Northern Pacific railroad at Brainerd with the cities of Minneapolis and Saint Paul. By railroad, Little Falls is about 30 miles below Brainerd and 90 miles from Minneapolis.

The falls, so called, are caused by the outcrop of the metamorphic rock belt which crosses this section of the state of Minnesota, and the obtrusion of a trap-dike has apparently increased the irregularity of the surface locally at this point. There is a natural descent of 7.3 feet in a distance of 2,100 feet from the head of the rapids.

Description of the falls.—The rock, which appears to be chiefly a variety of talcose slate, owing to a "system of joints" (Professor Winchell) has the appearance of dipping about 45 degrees down-stream.

A rib of this rock seems to cross the channel of the river at a slight angle down-stream, from the east to the west bank, and is the obstruction which forms the head of the falls. From one-third to one-half of the distance across from the east bank is a rocky island, starting at the head of the falls and running down-stream from 500 to 1,000 feet, called Mill island. It is, strictly speaking, an island only in high water, for the river, having worn the channel to the west of it more readily, has deserted the old channel on the eastern side, and except in full stages of the river the ridge of rock before mentioned extends across to the east bank in a line with the head of Mill island, dry or with only pools of water in the irregularities of the surface.

In ordinary stages the river practically flows through the narrow channel to the west of Mill island. This channel, which is about one-half the width of the river above the falls, is in the neighborhood of 300 feet wide. Both banks are about 15 feet high at the head of the falls, rising steeply from the river. On the west the land then runs back level into a rather swampy region; on the east it is slightly rolling, but yet constitutes a sandy, loamy plain, on which the village of Little Falls is laid out. These banks at the head of the falls are mainly the rugged projecting rock, slightly covered with earth. On the west side the trap referred to shows itself. Passing down from the head of the falls, the banks consist of sandy loam, underlaid by sand and gravel, then stiff clay, and finally by the solid rock. It does not seem probable that in the lower part of the falls the rock extends much above the level of the water-surface at the crest of the falls, although constituting the main portion of the bank at the crest. Passing down the falls, the water-surface soon descends to from 20 to 27 feet below the top of the banks.

Mill island presents an abrupt rocky face up-stream, its sides gradually becoming more earthy toward the lower end. It is of about the height of the surrounding land, and has a timber-growth upon its surface.

The river runs close to the west bank, but on the east the bank proper recedes from the crest of the falls, leaving a flood plain, considerably broken up by the action of the water, and partly occupied by the old channel, which runs close along the side of Mill island. The east bank approaches the river again at a point some 2,000 feet or more below the head of the falls. There is considerable timber on the east bank below the village, and the west bank of the river is also covered with timber, apparently consisting very largely of oak.

Present condition of the power.—A number of years ago there were some mills in operation at Little Falls, run by the water-power there, with a head of 8 feet. For some reason rather difficult to understand, the dam was constructed 200 feet above the head of Mill island instead of at the fine site afforded at the crest of the falls. It was carried away by the river, and now no use whatever is made of the power. The property is owned in the village, and it is said that this and all the interests connected with the power could be readily bought. Those undertaking its improvement would meet with every encouragement from the inhabitants of the town.

As the river is pronounced a navigable stream it is very probable that some arrangement would have to be made with the government before a dam could now be constructed. Perhaps, if the upper river is ever really improved for actual navigation, a lock will be required in any dam built at Little Falls. At all events, a sluice would be required for the passage of logs which are sent down the river in immense numbers during the spring and the June rises.

Regarding the use that could be made of the power, the first thought is employment for saw-mills; a considerable amount of the logs which now float down to the mills below might be caught and sawed into lumber at this place, and then shipped more directly to meet the prairie demand along the line of the Northern Pacific railroad. There is a road projected west from Little Falls, to be called the Little Falls and Dakota railroad, and if this is built there will then be direct communication with the immense wheat regions westward. There would then be every opportunity for the successful use of this power in the grinding of a part of the wheat which now finds its way to Minneapolis, or else passes in bulk to the sea-board. As it is, there would probably be enough wheat obtained in the surrounding region to give a moderate business to those seeking it. Other forms of manufacturing can be carried on advantageously at Little Falls as the country becomes more developed.

Plan of improvement.—It requires only a very short inspection to perceive the great natural advantages afforded at Little Falls for the improvement of its water-power. By far the best place for erecting a dam appears to be from each shore to Mill island, at the head of the falls. There is an excellent rock bed, with steep rocky abutments for the dam, both at each shore and at the island, while the length of dam required is comparatively small. A water-way and sluice-way for logs could be constructed in the west channel, and across the forsaken east channel

a high dam could be built above high water. Mills might be stationed along the length of this east channel dam. Canals could be excavated from the dam along each bank to convey power. On the east side of the river mills built in the old flood-plain already described could be fed from such a canal, using the deserted east channel as a tail-race. This could be deepened and the head of water increased up to the dam.

The construction of a canal on either the west or the east bank would require considerable rock excavation at its head. It is the impression of those familiar with the locality that the west side canal could be more easily constructed than that on the east or village bank, as the rock lies at a lower level. The construction of a side-track from the railroad, which is half a mile to the east, is entirely feasible.

If saw-mills were erected it would be best to run the dam across the island and then up-stream some distance, and so across the river, in order to afford "boomage" room for the logs.

Power available.—The next point to consider is the actual power available. The following are the figures relating to the profile of the water-surface: From the crest of Elk rapids to the crest of Little falls, a distance of very nearly 3 miles, the fall is almost 13 feet. At Little falls the total descent at an ordinary low stage is 7.3 feet in a distance of 2,112 feet. Of this there is a fall of 0.67 foot in 100 foot, and in one place 1.59 foot in a distance of 30 feet. Below Little falls for a distance of 4.7 miles the average slope is 3.40 feet per mile.

It is stated that the water-level could be raised at least 10 feet at the crest of the falls without flooding land above to any great extent; this would flood out the most of Elk rapids. It is perfectly practicable to construct a dam at Little falls raising the water to this level, and probably a higher level could be maintained without any injury to property. A 10-foot dam would give a total head at Little falls of over 17 feet, say 16 feet for the average.

The table gives the ordinary low flow at Little falls as 3,483 cubic feet per second, affording, under a head of 10 feet, 3,951 theoretical horse-power; and the average flow as 7,899 cubic feet per second, giving, under a head of 10 feet, 8,969 theoretical horse-power. Hence, under the available head of 16 feet, there could be obtained at a low estimate, with the ordinary flow, 6,320 theoretical horse-power; and with the average flow, which represents the condition under a complete application of the reservoir system, 14,350 theoretical horse-power.

THE RIVER FROM LITTLE FALLS TO SAUK RAPIDS.

In this distance of 31 miles the descent of the river is rapid, the average slope being 3.1 feet per mile. The chief points of concentration of this descent are: Pike rapids, Cashe's rips, McDougal's rips, Blanchard's rips, and Watab rapids. The total fall is slight at these places, only amounting to 1 or 2 feet, but the intervening slope is great. Thus for the 4.7 miles from Little falls to Pike rapids it is 3.4 feet per mile; below Pike rapids for a distance of 6.7 miles it averages 5.43 feet per mile. Cashe's rips are nearly 3 miles below Pike rapids. The bed is there rock in place. Blanchard's rips are about 2(?) miles below Cashe's rips. There the bed is rock, and the fall 1.80 foot in 1,356 feet. Below Blanchard's rips for a distance of 1.7 mile the average slope is 3.97 feet per mile; then for 21 miles below this it averages only 1.5 foot per mile.

At Watab rapids the bed is rock, and the river falls 2 feet in 800 feet.

The large slope of the river in the upper part of this section gives a possibility of utilizing the power by constructing dams and backing the water up-stream without flooding very far back.

Proposed improvement.—It has been proposed to build dams, one at Cashe's island, with a head of 13 feet, and another at Blanchard's rips, with a head of 10 feet. The first would probably flood back to Pike rapids, and the second to about the foot of Cashe's rips. The flow of the river is essentially the same at these places as at Little falls. With the ordinary low flow the theoretical power would be, under a head of 13 feet, 5,136 horse-power; and under a head of 10 feet, 3,951 horse-power. With the average flow the theoretical power under the heads given would be, respectively, 11,660 and 8,969 horse-power.

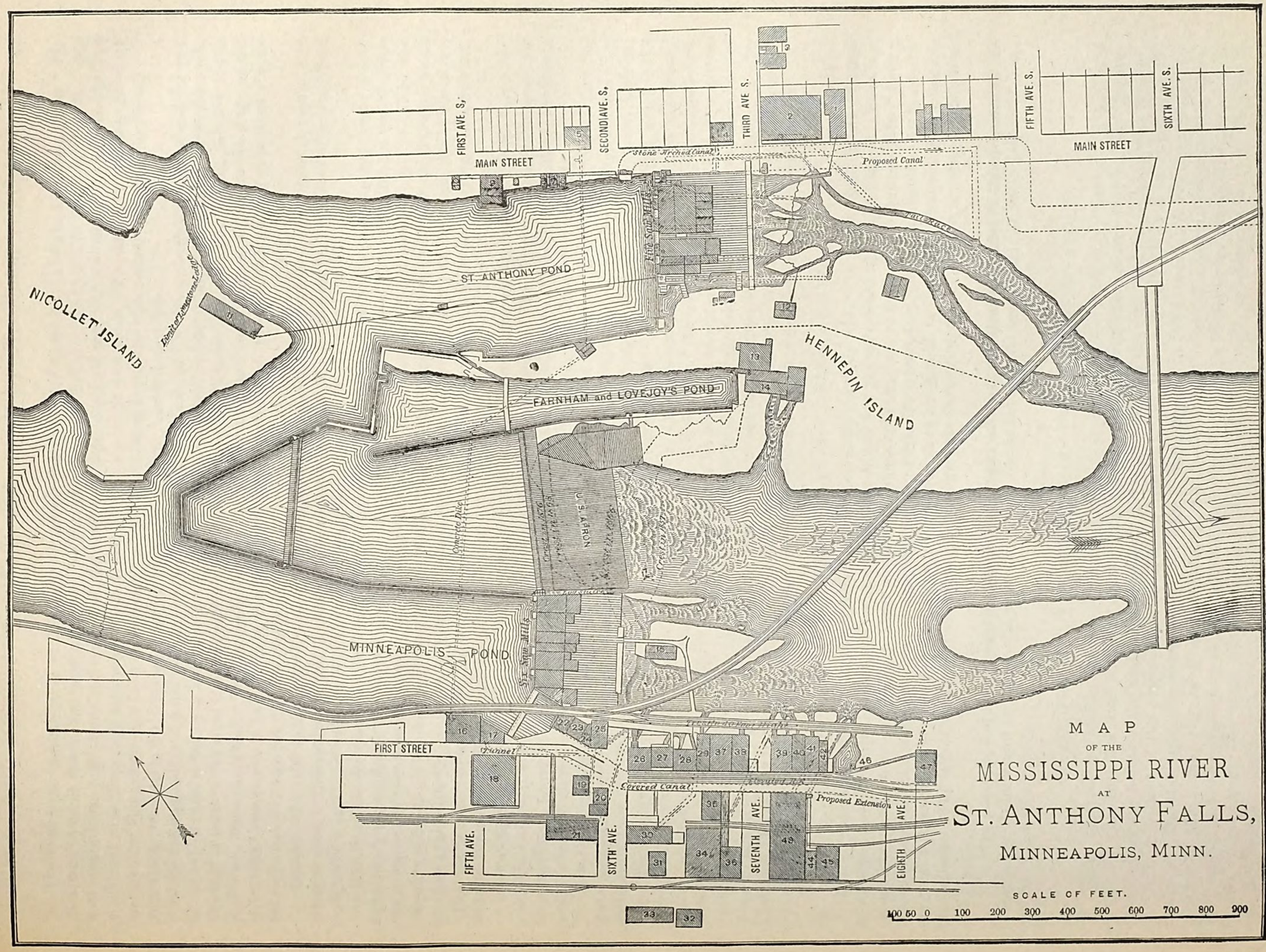
The total fall from the foot of Little falls to the head of Sauk rapids is 95 feet, and undoubtedly there are several places at which powers could be utilized, with what would be in the eastern states a reasonable outlay.

SAUK RAPIDS.

These are among the principal rapids above Saint Anthony falls. The descent, as given by Major Allen, is 11.3 feet in 4,224 feet. At a lower stage of water it has been estimated at 17 feet in 4,000 feet. The little village of Sauk Rapids is situated on the east bank. The Sauk river, draining 968 square miles, enters from the west at the head of the rapids.

Saint Cloud is about 2 miles down the river upon the west bank, where the Saint Paul, Minneapolis, and Manitoba railroad crosses. A branch of the Northern Pacific railroad passes through the village of Sauk Rapids. A highway bridge crosses the river at this place about 1,500 feet below the mouth of Sauk river. Although at Sauk rapids is the highest improved power upon the Mississippi, yet it is so little utilized as scarcely to deserve the name. One flouring-mill, of 250 barrels capacity, contains all the machinery run by an available power of over 5,000 horse-power in low water.

The river here flows over a hard rocky bed, consisting of gray granite, a part of the belt which passes west and southwest across the state. This Sauk Rapids granite consists very largely of quartz, and is a fine building-stone of great strength. It takes a fine polish, but is liable to contain spots of dark hornblende, which may disfigure the surface. This rock gives an excellent foundation for dams.


MAP
OF THE
MISSISSIPPI RIVER
AT
ST. ANTHONY FALLS,
MINNEAPOLIS, MINN.
SCALE OF FEET.
100 50 0 100 200 300 400 500 600 700 800 900
NICOLLET ISLAND
HENNEPIN ISLAND
ST. ANTHONY POND
FARNHAM and LOVEJOY'S POND
MINNEAPOLIS POND
U.S. APRON
Stone Arched Canal
Proposed Canal
Tail Race
Concrete Pipe
Tunnel
Covered Canal
Proposed Extension
FIRST AVE. S.
SECOND AVE. S.
THIRD AVE. S.
FIFTH AVE. S.
SIXTH AVE. S.
MAIN STREET
FIRST STREET
FIFTH AVE.
SIXTH AVE.
SEVENTH AVE.
EIGHTH AVE.

The west bank is some 30 or 40 feet high, consisting chiefly of gravel and clay, underlaid by the granite. The east bank is much lower, and immediately at the dam it is solid granite, overlaid by a thin covering of earth. The dam starts from just above the bridge, at the east bank, runs out half way into the channel, which is here 600 or 700 feet wide, then runs up-stream 400 feet, and then across to the west bank. The dam is built of log crib work and stone. The granite has been extensively used in constructing it and the abutments. The immense number of logs which come down the river each spring pass over the dam near the west bank.

The flouring-mill is situated just below the bridge, at the east side of the river, about 2,500 feet above the foot of the rapids, and is fed by a short canal formed by building a retaining-wall a short distance out from the bank. The mill is built in the river channel, and a wing-wall passes some distance down-stream, keeping the flow of the river away from the wheel. The head obtained at the mill varies from 9 to 12 feet, according to the stage of the river; 100 horse-power is used. There is difficulty from back-water when the river is high, and once there was an ice-gorge below which flooded the rapids.

Between the mill and the bridge is an unoccupied building, originally intended as a railroad repair- and machine-shop. The abutments and masonry walls about the eastern end of the dam bear evidence of having been designed for extensive works, which have never been built.

History of the development.—The reason of the imperfect improvement of this fine power appears to be chiefly unfortunate management and conflict of interests. As nearly as can be ascertained, there was first incorporated the Sauk Rapids Water-Power Company, on the east side, which failed, and by foreclosure of the trust-deed the property passed into the hands of Mr. William F. Davidson, of Saint Louis, Missouri, who now owns the power on the east side, with the exception of the 100 horse-power used by the flouring-mill. On the west side of the river, where there is no improvement, the ownership of the power is disputed by Mr. William Dawson, of Saint Paul, and the Sauk Rapids Manufacturing Company.

It was the opinion of Mr. J. A. Stanton, the proprietor of the flouring-mill, from whom the above information was obtained, that there is no definite prospect for further improvement. The location is good, however, for manufacturing, being on the railroad, and only 75 miles by river from Minneapolis, and it is hardly probable that many years will elapse before legal difficulties will be settled and use will be made of the power.

It is possible to utilize the power upon both sides of the river, but the nature of the banks is such that the eastern one can be more readily improved, judging from the limited investigation permitted by the severe winter weather of 1880–'81. On that side the canal could readily be continued and a large number of mill-sites supplied. There are already some two or three available besides the one now in use. Under the head of 10 feet, which is the average in practical use now, there are, according to the table, 4,678 theoretical horse-power available in ordinary low water, and, with the average flow, 10,408 theoretical horse-power. By continuing the present canal it is probable that a head of very nearly if not quite 15 feet can be obtained, except in high water. There is a mill on Sauk river near its mouth, and the raising of the dam would flood the water back upon its wheel, but the owner of this mill has given full right of flowage, so the dam can be raised and the total head somewhat increased. Under a head of 15 feet the total theoretical power would be 7,000 horse-power with the ordinary low flow, and 15,600 horse-power with the average flow, or the flow obtainable under a complete application of storage-reservoirs.

THE RIVER FROM SAUK RAPIDS TO SAINT ANTHONY FALLS.

From Sauk rapids to Saint Anthony falls there are no rapids specially worthy of note. Still, in this distance of 74 miles, the river falls 183 feet, with an average slope of 2.47 feet per mile, making a rapid current. There are some eight small rapids, where for a short distance the slope is at the rate of from 4 to 10 feet per mile. Among the chief ones may be mentioned Smiler's rapids, Battle rapids, Houghton flats, and Coon rapids. At the latter the total fall is 6.9 feet in 3,600 feet, and the worst obstruction to navigation in the entire distance of 74 miles has here existed. The bed of the river at all the rapids appears from the engineering reports to be formed of bowlders and gravel.

It is very possible, and even probable, owing to the rapid fall, that practical sites exist in this distance for the construction of dams and the improvement of the power, but so far as could be ascertained no project of this kind has ever been entertained.

WATER-POWER OF SAINT ANTHONY FALLS, AT MINNEAPOLIS.

Above the junction of the Minnesota river the Mississippi has a general southeast direction. It has been flowing for more than 500 miles between banks mainly carved out of the drift which covers that region. Eight or 9 miles above the mouth of the Minnesota it suddenly cuts its way through the rock, and forms the "Owah-Menah", or "Falling Water", of the Sioux—the falls of Saint Anthony. At this place is the largest water-power of the northwest. On the right or western side of the falls is Minneapolis; on the east bank is Saint Anthony, now included in the former city as East Minneapolis. About the falls is collected a population of nearly 47,000 inhabitants. A yearly average of at least 790,000 cubic feet of water falls 75 feet every minute, and the result is 112,000 horse-power. The large business done by the city of Minneapolis is almost entirely in the line of manufacturing, as shown by the following figures, taken from the report of Mr. Charles W. Johnson, special agent of the Tenth Census. Practically all the power used in manufacturing is given by the falls.

Character and value of manufactures.—Sales during the census year in Minneapolis:

Total of all kinds	$39,526,200
Total of principal manufactures	27,171,200

The latter amount is thus distributed:

Flour	$20,364,200
Lumber, laths, and shingles	2,098,000
Feed and commission	1,934,000
Agricultural implements and machinery	1,500,000
Miscellaneous manufactures	1,275,000

Over two-thirds of the entire business of Minneapolis is manufacturing, and of this three-quarters is milling. The industry which ranks next to milling in value is the manufacture of lumber. About Saint Anthony falls is a group of flouring-mills which are said to give this point the second position as a milling center in the world, the only place outranking it being a town in Hungary. All this immense business has sprung into existence within the last quarter of a century. The growth of business has only kept pace with the rapid advance westward of the population, aided, of course, by the great advantages of the water-power. The character of the two chief industries, milling and lumbering, is the natural result of the character of the country and of the time. When the first enterprising settler began on a large scale to use the falls, it was to saw the pine lumber which grew in such quantities at the headwaters of the river. As the resources of the wheat-producing prairie-soil were realized, improved flouring-mills were built. The pine forests lying northward are being cut away at the rate of over 200,000,000 feet (board measure) per year, and the time will come when the saw-mills of Minneapolis will lose their occupation. The wheat-fields to the westward are, on the contrary, widening each year with marvelous rapidity, and the milling interests seem to have just entered upon a field of almost boundless scope, so far as the raw material is concerned. As the country becomes older, and the inhabitants accumulate more wealth, other branches of manufacturing will probably increase.

The peculiar advantages of Minneapolis for communication with the surrounding country have been already alluded to in the "General Remarks upon the Water-Power of the Northwest". Through-lines connect it with the eastern seaports and with the prairie region westward. It lies directly in the line of traffic between a large part of the west and the eastern coast.

Flouring and lumbering interests.—There were in operation here in the census year twenty-eight flouring-mills, representing a capital of $3,816,000, with an annual production whose value has been already stated. There were also fourteen lumber-mills, with a capital of $1,945,000. The lumber-mills produced 158,555,000 feet (board measure) of lumber, 27,668,000 laths, and 37,940,000 shingles.

The flouring-mills produced 3,227,993 barrels of wheat-flour, or 10,313 barrels for each working day, using 16,807,186 bushels of wheat, or 53,697 bushels per day. Thus every day 10,000 barrels of flour left the mills, and 54,000 bushels of grain, requiring about nine trains of twelve cars each, were wheeled into them. At the time of collecting these statistics the largest of the mills had a capacity of 1,500 barrels per day. Since that time it has been enlarged to 3,000 barrels, as was also done with another mill, and a new mill has been built with a capacity of 5,000 barrels. Thus the total capacity per day was raised to about 18,000 barrels.(*a*)

The total power in use is in the neighborhood of 13,000 horse-power, hence the manufacturing might be increased to at least four times its present amount without taxing the ordinary low-water power of the falls, if properly utilized. The truth is, that even now there is a dearth of water in the low season, but, as will be shown later, this is due to waste in its utilization, and not to any lack of power if the situation were fully improved.

The following is a list of the manufacturing establishments in the city of Minneapolis, Minnesota, with a designation of the kind of mill or manufacture, and the names of certain of the mills. The figures indicate the location upon the map of each of the several establishments:

1.—Flouring-mill, "North Star."
2.—Flouring-mill, "Pillsbury A."
3.—Sashes and doors.
4.—Flouring-mill, "Phœnix."
5.—Iron-works, "Union Iron Works."
6.—Machinery.
7.—Machinery.
8.—Machinery.
9.—Eaves-troughs.
10.—Mattresses.
11.—Various industries.
12.—Furniture.
13.—Paper-mill.
14.—Saw-mill.
15.—Cotton-mill, "Minneapolis."
16.—Saw-mill.
17.—Water-works.
18.—Flouring-mill, "Crown Roller."
19.—Flouring-mill, "Model."
20.—Flouring-mill, "Dakota."
21.—Flouring-mill, "Standard."
22.—Flouring-mill, "Arctic."
23.—Flouring-mill, "Union."
24.—Flouring-mill, "Holly."
25.—Flouring-mill, "Cataract."
26.—Flouring-mill, "Empire."
27.—Flouring-mill, "Minneapolis."
28.—Flouring-mill, "Pillsbury."
29.—Flouring-mill, "Excelsior."
30.—Woolen-mill, "North Star."
31.—Flouring-mill, "Anchor."
32.—Machinery.
33.—Car-shop.
34.—Flouring-mill, "Washburn C."
35.—Elevators.
36.—Flouring-mill, "Washburn B."
37.—Paper-mill.
38.—Flouring-mill, "Northwestern."
39.—Flouring-mill, "Pettit."
40.—Flouring-mill, "Zenith."
41.—Flouring-mill, "Galaxy."
42.—Elevators.
43.—Flouring-mill, "Washburn A."
44.—Elevators.
45.—Flouring-mill, "Humboldt."
46.—Wheel for elevated railroad.
47.—Flouring-mill, "Palisade."

a On December 4, 1881, four of the medium-sized mills were burnt down.

GENERAL DESCRIPTION OF THE LOCALITY.

About three-quarters of a mile above the falls of Saint Anthony is a small island called Boom island, and just below this the head of Nicollet island. This extends down-stream some 3,000 feet or more, dividing the river into a west channel and an east channel, which latter is considerably the smaller of the two. At the lower third of the island a suspension bridge across the west channel connects the island with the main portion of the city of Minneapolis, while a stone arched bridge of several spans crosses the east channel into the other division of the city.

About 250 feet below the foot of Nicollet island is Hennepin island. This island, about 2,300 feet long, is narrow at the upper portion, widening out to over 500 feet at the lower end. The falls occur opposite Hennepin island. In the west channel their crest is about 700 feet below the foot of Nicollet island; in the east channel it is about 700 feet still farther down the river. Just above the crest in the west channel the total width of the river from bank to bank is 1,530 feet; the west channel proper being 960 feet and the east channel 450 feet wide. The banks of the river above the falls are from 15 to 30 feet high.

If the falls were left in their natural state they would show a vertical pitch of 20 or 30 feet, with rapids above and very strong rapids below them. The general level of the ground remains the same below the falls, but the banks become steep rocky bluffs, which rise above the bed of the river nearly 100 feet a short distance below. These bluffs bound the river on each side to Fort Snelling, where the Minnesota river enters the valley; there they separate, including between them the much larger valley of the river below.

Water-power companies.—The natural appearance of the falls is entirely obliterated by the means used for improving their power. There are three companies claiming the right to them—the Minneapolis Mill Company on the west side of the river, the Saint Anthony Falls Water-Power Company on the east bank, and the firm of Farnham & Lovejoy between the two, on Hennepin island. These concerns have constructed dams and training-walls, which divert the flow of the river almost entirely through their races in low water. On a line just above the crest of the falls a dam extends from the west bank out into the river 350 feet; then runs up-stream about 1,000 feet; then down and across to Hennepin island; then down Hennepin island and across the east channel to the east bank, about 400 feet above the crest of the east channel falls. There is a water-way of 450 feet left in the west channel between the dam of the Minneapolis Mill Company and Hennepin island. In this distance the falls have been covered by the United States government with an immense wooden apron, or chute, to protect them from the wear of the water. The water on the west and east sides is mainly carried around the falls and discharged from the bluffs below. Thus the falls of Saint Anthony would hardly be recognized by those who had visited them when nothing but the rock, the foaming water, and the trees were to be seen.

HISTORY OF THE FALLS AND OF THEIR IMPROVEMENT.

Early explorers.—The enforced journey of Father Hennepin up the Mississippi has been alluded to on a preceding page. He was probably the first white man to gaze upon the falls, which his Sioux captors called Owah-Menah. Visiting them in July of the year 1680, he probably found the river at a high stage, and was much impressed by their grandeur, stating that "it indeed of itself is terrible, and hath something very astonishing". He gave the falls the name of his patron saint, Saint Anthony of Padua. Hennepin describes them as being from 50 to 60 feet high (another translation gives from 40 to 50 feet). Since his time, Carver in 1778, Lieutenant Pike in 1805, Major Long in 1817, and after him several others have visited the falls, and written descriptions of them varying more or less; some evidently exaggerations, while with others the differences are no more than are due to the rapid changes which have taken place.

Government occupation.—The era marked by the entrance of pioneers and settlers in this new country hardly began with the close of the last century; it is true that the trappers and traders of the fur companies had bartered with the Indians along the line of the great lakes, but very little, if any, permanent settlement had been effected. The following facts relating to the improvement of the power at Saint Anthony falls are taken mainly from a series of articles written for the *Northwestern Miller*, by Mr. F. E. Hesler, formerly of the *Minneapolis Evening Journal.*

In 1819 the United States government began the erection of a military outpost on the bluff at the junction of the Minnesota with the Mississippi. This was called Fort Snelling, and is still occupied as a base of supplies for the frontier.

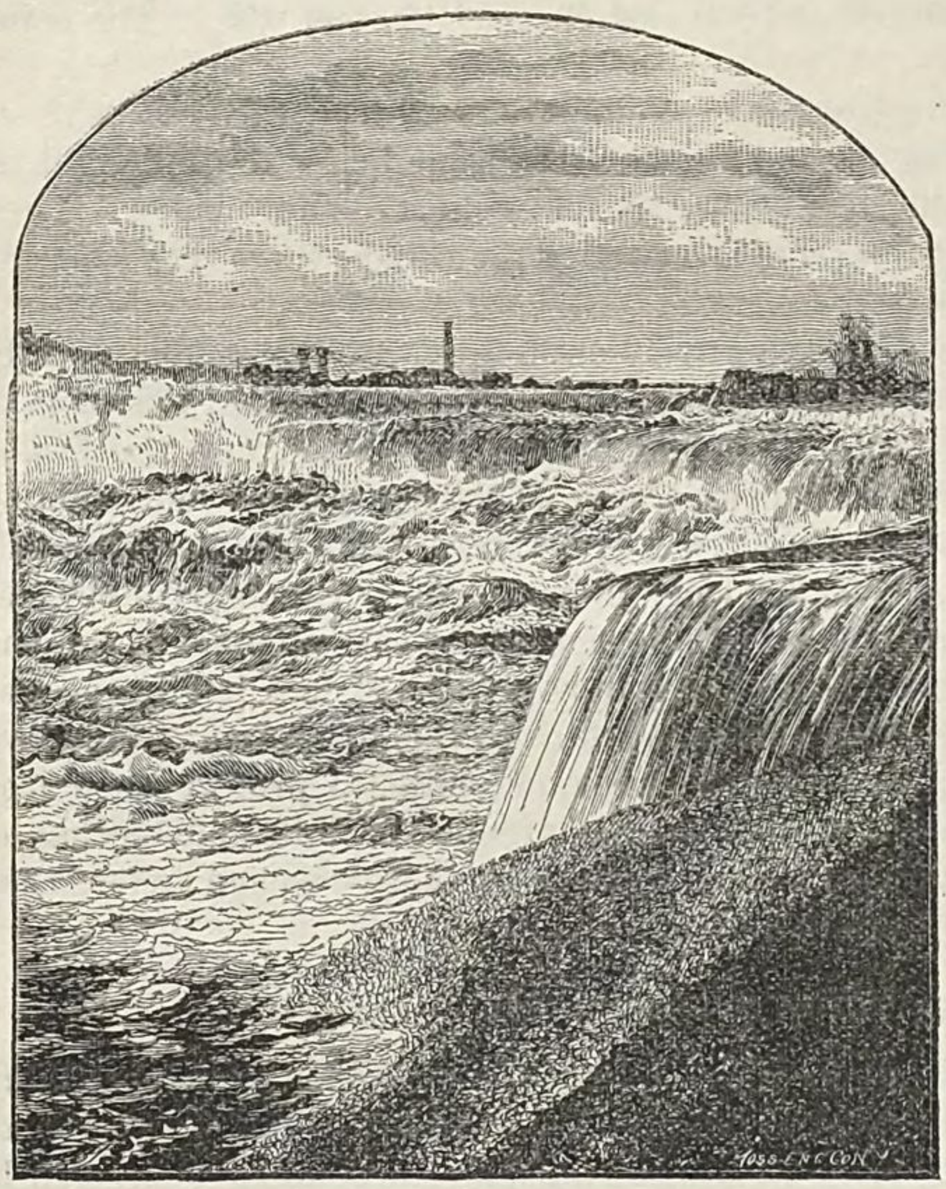
In 1825 the government built a saw- and grist-mill on the west bank of the river just below the brink of the falls. This, the first mill at Saint Anthony falls, was finally allowed to fall to ruin.

First extensive improvement.—In 1848 the first private improvement was inaugurated. Mr. F. Steele then built a dam across the east channel to Hennepin island, then up that island to the foot of Nicollet island, forming a pocket of the east channel. He erected four saw-mills, working under a head of 6 feet, and soon afterward built seven more. A Boston firm connected with Mr. Steele was desirous of relinquishing its right, and paid him $5,000 to allow it to retire. Mr. Steele made various sales and partnerships with several individuals, and finally in 1856 all those interested sold their rights to the Saint Anthony Falls Water-Power Company.

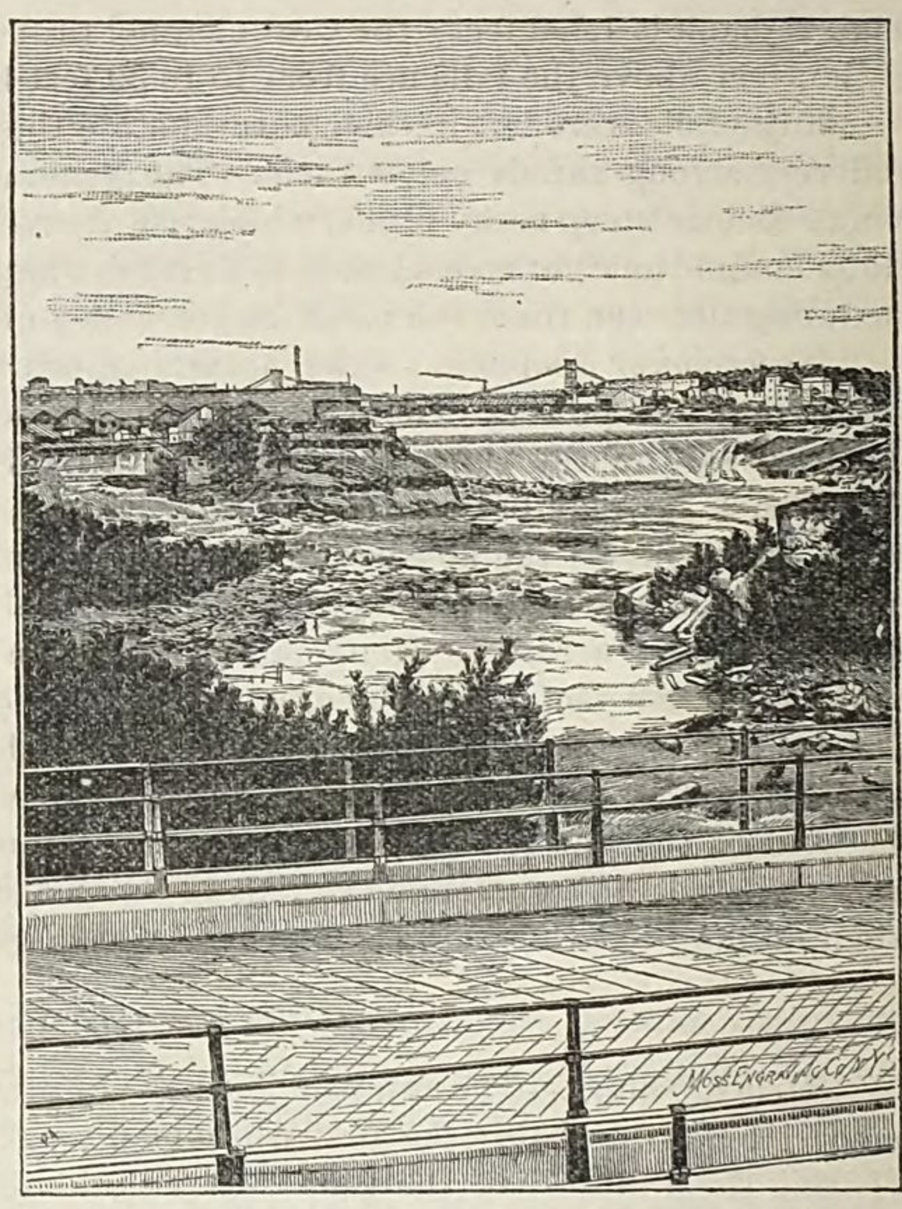
Organization of water-power companies.—This company was chartered by the territorial legislature on February 26, 1856, and on the next day the Minneapolis Mill Company received its charter, both of them perpetual.

Previously to the incorporation of these two companies the step had been taken which has resulted in the present immense milling business.

Development of the flouring interest.—The old government feed-mill built for the supply of Fort Snelling had long since disappeared, but in 1851 a Mr. Rogers roofed in a portable feed- and grist-mill on the east side; then, in 1852, in company with Mr. Steele, he extended it, erecting a one-story building and setting up two runs of stones. A thirty-two bushel grist, which came one day, was a wonder at that time. In 1854 the Island mill was started with three runs of stones, afterward increased to five. The country was then fast being settled, and although many thought this mill would not be a success, yet it paid for itself in two years. The first flour shipped out of the town was in 1858 by a farmer, a Mr. Getchell, who took that means of sending some money to his old home in New Hampshire. This soon resulted in an order to the mill for 100 barrels.



Saint Anthony falls as they were.



Saint Anthony falls as they are.

The mill was subsequently enlarged, but was destroyed by fire, as were also two others. A third mill shared the destruction caused by the break in the tunnel, which will be mentioned farther on.

In the mean time the Minneapolis Mill Company was not idle. No power had been used up to 1857, but then they began the construction of a dam and canal, and in 1858 the Cataract mill was built. After that came the City mill, the Union mill, the Arctic mill in 1866, and others in succession, until now there are altogether, upon both sides of the river, twenty-nine mills.

On May 2, 1878, occurred the great fire and explosion among the mills on the west side, when six large mills, representing eighty-eight runs of stones, were destroyed. A similar catastrophe on a much smaller scale occurred on December 4, 1881, when one cotton-mill and three flouring-mills were destroyed. These were merely interruptions, however, in the prosperity and development of the place.

The development of other manufacturing interests has been lost sight of in considering the great increase in the flour production at the falls; but various other industrial establishments, as machine-shops, woolen-, paper-, and cotton-mills, sash and door factories, etc., now take their power from the river.

Saint Anthony falls has not been exempt from the well-nigh universal litigation arising from conflicting water-power interests, but by recent adjustment of disputed interests the power seems now clear from all obstructions in the way of complete improvement.

GEOLOGICAL HISTORY OF THE FALLS.(*a*)

The immediate future of the falls is intimately connected with their geological character. It has already been mentioned that the river above the falls is bounded mainly by drift bluffs, but below them it sinks into a gorge about one-quarter of a mile wide, bounded by nearly vertical rock bluffs, which gorge continues to the junction

a Mainly gathered from Professor N. H. Winchell's report as state geologist.

with the Minnesota river. At the falls the river suddenly breaks through the rock strata, and flows along the lower level of the bottom of the gorge. In order to understand this a knowledge of the character of the strata is necessary.

Geological section.—At the falls it is as follows:

1. Drift, consisting of loam, clay, and gravel of varying thickness.

2. Trenton limestone, hard, compact, except for the many seams running through it, bluish in color, weathering to a buff color. It is generally as follows, in descending order: Impure limestone, from 9 to 12 feet; calcareous shale, from 4 to 6 feet; argillaceous limestone, 15 feet.

3. A layer 15 inches thick of hard, calcareous shale.

4. Saint Peter sandstone, 164 feet thick at the falls. This consists almost entirely of pure quartz sand, and is consequently white, except where stained by iron. There is so little lime that the grains are scarcely held together. The first 2 or 3 feet in depth are considerably impregnated with argillaceous matter, and are consequently quite hard. The rock can in any place be excavated with the pick, sometimes even with the hand. Where dripping water has had access to it the grains are more firmly cemented. It is very easily eroded by running water, disappearing almost like a lump of sugar.

5. Below the sandstone is the lower magnesian limestone.

The first four divisions are the only ones visible at the falls. The Trenton limestone there dips toward the southeast; at the iron bridge, which crosses the river some distance below the falls, the dip is very slight; at the falls it is 1 inch in 100 feet; a short distance above it is 3 or 4 inches in 100 feet; and on the east side, opposite the suspension bridge, it is 5 inches in 100 feet.

The bed of the river at the crest of the falls is in the Trenton limestone, of which there is a depth of about 16 feet between the bed of the river and the sandstone below. The bed below the falls is in the Saint Peter sandstone, but is strewn with fragments of all sizes of the Trenton limestone.

Causes producing the falls.—It is easy now to understand the cause of the existence of the falls. The water wears out the soft sandstone at the base, but is prevented by the hard cap of limestone from further action. The projecting limestone ledge, undermined by the wearing away of its support below, gradually breaks away, but always preserves a vertical face to the falls. Were it not for the stratum of limestone protecting the soft rock below, the river would long since have worn its bed to a uniform slope.

The above mentioned fact implies a gradual recession of the falls, and this is exactly what has taken place. In the same way as the gorge below Niagara falls has been carved out by the passage of the cataract up-stream, so have the falls of Saint Anthony passed upward from the valley of the Minnesota to their present position, cutting out the gorge we have already described.

The original position of the falls was never farther down the river than Fort Snelling, where the Minnesota enters. In this connection we may refer to the apparent fact that in the Glacial age the Minnesota was the real continuation of the main drainage trunk, and the stream represented by the present Mississippi above the junction was a comparatively small river tributary to it. Although small in comparison with the volume of the Minnesota at that time it was nevertheless much larger than at present.

Ancient channel of the Mississippi.—Instead of entering the ancient trough of the Minnesota where it now does, at Fort Snelling, the Mississippi left its present bed above Minneapolis, where Bassett's creek now flows into it, and running northwest of its present course entered the Minnesota valley at a point somewhere above Fort Snelling. This ancient course can be traced now. The river ran along the line of strike of the Trenton limestone, which probably formed a training-wall to the river, precisely as the hard lower magnesian limestone does now to the Wolf river in eastern Wisconsin.

The old bluffs, rounded off and partly concealed by the covering of drift, can yet be traced. The bed was cut over 100 feet deep in the Saint Peter sandstone, and there being no hard protecting cap of limestone there were no falls produced. Now the trough is nearly or entirely filled with the drift, and it was during the spreading of this in the Glacial age that the course of the river was changed to its present position. As the trough was filled up the river flooded back and the level rose, until, breaking across the limestone barrier, it for the first time fell down the face of the old river bluffs at Fort Snelling, and gave birth to Saint Anthony falls. Just how long the falls have taken to recede to their present position it is impossible to tell, but Professor Winchell, by comparing the descriptions given by the various travelers of the positions of the falls, fixes upon a rate of recession, and, with the hypothesis of uniformity of conditions in the past and present, calculates the length of time to have been from 8,000 to 12,000 years. Of course all such calculations must be taken with an understanding of their uncertainty.

Danger of the destruction of the falls.—A rather startling fact is apparent on an examination of the river-bed; the belt of outcrop of the Trenton limestone is not far to the north of this region, and, as the river-bed is worn somewhat into this bed of limestone above the falls, it happens that this hard, protecting layer, which is only 16 feet thick at the crest of the falls, thins out to a feather edge in the bed of the river and ceases entirely, just 1,200 feet above, in the west channel. If left to itself it would not be long before the last of the limestone would be gone, and the river would rapidly wear away the soft rock below, until nothing but a mass of foaming rapids would be left. This would be a very serious catastrophe to the water-power interests at Minneapolis, and there was imminent danger a few years ago of its actually taking place.

Rate of recession.—The rate of recession of the crest of the falls for at least the two centuries preceding their utilization was from 5 to 7 feet per year. When the improvements were commenced the recession became much more rapid. A high dam was thrown entirely across the east channel, another, 400 feet long, was thrown out from the west bank into the west channel, and the flood discharge of the river was practically restricted to the narrow passage, of 450 feet in width, between this dam and Hennepin island. This increased to a great extent the erosion at the base of the falls.

Then, again, the V-shaped dam above this water-way left in low water a large surface of the limestone bed of the river exposed to the action of frost in cold weather. This caused disintegration of the seamy limestone. The result has been that from the year 1857 up to 1876 the crest receded in the west channel 330 feet, or 17.2 feet per year. At this rate it would only require seventy years more for the falls to break away the last trace of the limestone.

Break in the limestone bed.—Then another cause of danger occurred in comparison with which the first was of slight importance. Some persons became possessed of the right to the use of a portion of the power on Nicollet island, and the idea was conceived of running a tunnel from the foot of the falls under the bed of the river to the foot of the island. There it was to be used as a tail-race by mills stationed upon the island. This was apparently an admirable plan, but it came near proving the destruction of the falls. Starting from the falls the tunnel was easily excavated in the soft sand-rock; everything was progressing finely, and a point had been reached about half way between Hennepin and Nicollet islands, when the water was found to be oozing through the roof and sides of the tunnel. Under the hydrostatic pressure of the river above it was finding its way below the upper edge of the limestone and was gradually wearing out the softer rock below. Finally, on October 4, 1869, the situation was very alarming, and suddenly, hardly giving the workmen time to escape, the water rushed into the tunnel, rapidly wore away the sandstone support, and, the limestone caving in, a great opening was made in the bed of the river, down which the water poured with ever-increasing violence. The cry rang through the city, "the Falls are going out!" as indeed was the case. Various methods were tried to stop the flow, and a raft of timbers, brush, etc., was floated over the opening, only to be broken in pieces. It was eventually checked by building a crib-work coffer-dam around the place. A second break soon occurred, just below, and was likewise closed. On the 5th of April a part of the coffer-dam about the second break was destroyed by the ice, the water entered the tunnel, and part of the lower portion of Hennepin island was washed away, including a number of mills. By this time considerable money had been spent by the city and private individuals.

Maintenance of the falls.—In July, 1870, Congress came to their aid with an appropriation of $50,000. The plan of the government engineers was to clean out the tunnel and fill it with puddle up to the limestone, then to build a masonry wall entirely around the breaks, filling the inclosed space to above high water with clay and gravel puddle, and then riprap the surface. Considerable work was done in accordance with this plan up to 1874, three minor breaks occurring. In 1874 a commission of engineers recommended the building of a solid dike of concrete extending entirely across the river, under the limestone ledge. This work was done in two years. It consists of a solid wall of concrete, 38 feet high and 4 feet thick, cemented to the lower side of the limestone strata, and extending down into the sandstone. It is, altogether, 1,870 feet long. Starting 325 feet above the dam on the west side, it runs across to Hennepin island, then diagonally down it, and then across the east channel, about 200 feet above the dam.

In addition to this work on the tunnel the crest of the falls has also been protected. In 1866, and again in 1869, the water-power companies attempted to protect the falls by a woooden apron, but their work was carried away by the high water. They were finally aided in this by the government. During the fiscal year ending 1877 the government also built the two spill-dams above the apron to keep the bed flooded and protected from the frost. During the next fiscal year the apron was remodeled.

The above facts are taken from Mr. J. P. Frizell's account in the report of the chief of engineers for 1879. Altogether there has been spent by the citizens of Minneapolis about $334,500 upon the preservation of the falls, and by the United States government $605,000 up to March 3, 1879. A description of the dike, apron, and dams will be found on a later page.

Advantage resulting from the character of the associated strata.—This soft layer of sand-rock, while it has been the cause of so great an expense, is, nevertheless, from its position, a very valuable feature in the improvement of the power, aside from its being partly the cause of the existence of the falls. Lying directly under the limestone, it is just in the position for the excavating of tunnels to act as tail-races to the mills on the banks above, and being so soft its excavation is a very easy matter. This peculiarity is very extensively taken advantage of. The solid layer of limestone serves admirably as a roof to the tunnels, which are driven just below it. They will be more minutely described farther on.

CHARACTER OF THE POWER.

The average flow of the river, given in the table for the main river, does not by any means represent the actual condition of affairs from day to day. Swollen by the spring rains or the melting snow and ice, the flow past Minneapolis may be over 50,000 cubic feet per second; while under the action of a dry summer and fall or the freezing winter it may dwindle down to even 4,000 cubic feet per second. From Major Allen's report are obtained

the following average monthly conditions of stage and flow at Fridley's bar, just above Minneapolis, for the year 1875, which, as stated by him, was about an average year as regards the total flow for the year, although it may not have been in regard to distribution.

Table of monthly averages of flow, etc., at Minneapolis for 1875.

Month.	Average monthly stage above low water, in feet.	FLOW PER SECOND.			Theoretical horse-power under 75 feet head (average flow).	Effective horse-power under 75 feet head—efficiency of 75 per cent.—(average flow).
		Average for the month.	Maximum flow of the month.	Minimum flow of the month.		
		Cubic feet.	*Cubic feet.*	*Cubic feet.*		
March	2.00	.....	.....	.....	.....	.....
April	8.10	36,132	53,496	19,155	307,400	230,600
May	6.15	27,642	32,670	22,983	235,200	176,400
June	6.76	29,927	40,066	18,245	254,600	191,000
July	1.97	10,530	16,876	7,177	89,600	67,200
August	0.66	6,695	8,535	5,640	57,000	42,700
September	2.16	11,122	12,355	9,172	94,600	71,000
October	2.30	11,623	11,980	10,883	98,900	74,200
November(*a*)	1.57	11,919	12,739	11,244	101,400	76,100
December	0.92	.....	.....	.....	.....	.....
January	2.54	.....	.....	.....	.....	.....
February	1.96	.....	.....	.....	.....	.....

a Gaugings of the flow for November were taken only from the 1st to the 17th, inclusive.

Variation for the year 1875.—Starting with the 1st of March there was a gradual increase in the flow, caused by melting snow and ice and the rains, up to April 16, when the maximum of the year was reached, 53,496 cubic feet per second. The gauge then stood at 11.8 feet above low water. Then there was a gradual fall through May to the 29th, when the gauge stood at 5.2 feet, and the flow was 22,983 cubic feet per second. From the 29th of May the river began to feel the effect of the late spring and summer rains and rose until June 6, when it stood at 9.1 feet on the gauge, giving a flow of 40,066 cubic feet per second. It then fell continuously to August 16, when the gauge marked zero, and the flow up to the 19th was 5,640 cubic feet per second. From August 19 to September 7 the river rose to 2.5 feet on the gauge and a volume of flow of 12,355 cubic feet per second. From that time on to the 17th of November the river kept a pretty constant stage, not rising above 12,739 cubic feet per second, nor falling below 10,530 cubic feet per second. From November 18 to April 1 no record is given of the volume of flow.

Times of freshets.—The water-power owners state that there are ordinarily three annual rises in the river—the spring rise at the going out of the ice, usually in early April, generally not very great; the June rise, caused by heavy rains, which is generally the largest freshet of the year; and the fall rise, usually slight, caused by the fall rains. The average maximum rise for the year is between 6 and 8 feet.

The low water usually occurs from the latter part of July into the fall, and again in the winter months. It is generally considered that the lowest stages of flow occur in winter, especially if it is very severe, but the water-power companies do not base their calculations upon that flow. Mr. H. H. Douglass, agent of the Minneapolis Mill Company, states the average summer flow to be 15,000 and the average winter flow 10,000 cubic feet per second. Considering each of these seasons to include six months, the average flow of the year would be 12,500 cubic feet per second. As given in the table of the river it is 13,193 cubic feet per second. We take the estimate of 10,000 cubic feet per second for the average winter flow (there are many days when it is much less); and it is believed that the estimate given in the table of 6,000 cubic feet per second for the ordinary low flow, as defined in describing the tables, is on the safe side for the low season of summer, and may even be applied to the winter months, although, not having gaugings for that season, this cannot be positively asserted.

Power in use.—The total power used on the west side of the river is between 9,000 and 10,000 effective horse-power, with a head ranging from 12 to 48 feet, the average being, in the winter of 1880–'81, 23.6 feet.

The total power used on the east side, and on Hennepin island, is (including the large Pillsbury A mill) slightly more than 3,000 effective horse-power, with a head varying from 16 to 50 feet, averaging about 34 feet.

The total power in use is, hence, in round numbers, 13,000 effective horse-power, under an average head of about 25.5 feet, and assuming an efficiency of two-thirds, requiring a volume of flow of about 6,700 cubic feet per second.

Reasons for lack of water.—These figures serve to explain the fact that while the total theoretical power at an average stage of the river is over 100,000 horse-power, yet there is at times a scarcity of water, the mills drawing the level down nearly to the bed of the river, and the manufacturers are obliged to arrange for their mutua-

accommodation. Instead of making use of the total head of 75 feet, only about 30 feet is the average used. Then again, many of the arrangements are not the best possible for obtaining the maximum efficiency from the water and head used.

The improvement of the falls has not been from a comprehensive scheme, formulated at the commencement and completely carried out, but the first mills were built above the falls, using only the 12 or 16 feet of head afforded by the dam itself. Water was plenty, and there was no thought of want. Now tunnels are being driven, and the head is being increased for many of the mills. This will tend to reduce the difficulty from want of water, but cannot be relied upon entirely for that purpose. The expense is great, the work involving not only the excavation, but the putting in of a completely new set of wheels. Even supposing the head to be increased at all the mills, it is not probable that the average head used will be much over 50 feet for many years to come. About 70 feet is the head available, supposing canals to be carried down-stream for half a mile, and all the water taken to that point and then used, or supposing large tunnels to be started from that point and run up to the falls, using them as tail-races for all the mills. Such extensive improvements are theoretically possible, and perhaps at some future day will be put into a practical form, when the absolute necessity occurs for making available every horse-power; but at present they are not probable. Yet the two water-power companies upon the opposite sides of the river are endeavoring as much as possible to realize this ideal condition, and in the improvements now going on are pursuing the general plan just mentioned.

The constant tendency is to a better condition of affairs; but as more mills are built there will apparently be times, when the river is at its lowest, at which the supply of water will not be sufficient to meet the demands made upon it, just as at present. The proper way to meet this difficulty seems to be to continue making the utilization of the power more efficient, but also to strike at the root of the matter and endeavor to regulate the flow of the river.

Value of reservoirs to the water-power.—The upper Mississippi is far from being an unsteady stream, but during part of the year it may flow past Minneapolis at the rate of 35,000 cubic feet per second and then fall to 6,000 cubic feet; at one time barely affording enough water to supply all the mills now running, at another rushing over the apron at the falls, scarcely diminished by the amount taken by the mills. The proposed reservoir system has been already treated of. If this is carried out by the government upon the sources of the Mississippi, it will meet almost entirely this very requirement of the water-power interests. Of course it will be done, if at all, by the government, to improve the navigation of the river, and the flow would be regulated to further that interest; but at the same time it would act in favor of the water-power, because, so far as the flow is concerned, the interests of navigation and water-power are almost identical. The fact is that some of the chief opposition, especially in the state of Minnesota, to the application of the reservoir system by the government, arises from a feeling that it is being urged in the interests of the manufacturers of Minneapolis.

The physical peculiarities of the region above Saint Anthony falls have been already described on the pages relating to the deduction of the tables for the main river and its tributaries. It was shown that there was available for storage above Minneapolis an average yearly flow of slightly more than 13,000 cubic feet per second. The surveys conducted by Major Allen show that there is abundant storage capacity about the sources of the river, available at a practicable expense, for a very large amount of this average flow, and that, with the lowest estimates, a discharge of about 12,000 cubic feet per second past Minneapolis can be maintained during the low-water season of summer and fall.

Unless the autumn rains should fail, it is probable that the discharge could be maintained at nearly this amount during the winter months by a proper management of the reservoirs. The maintaining of a flow at all times of at least 12,000 cubic feet per second would be of immense value to the water-power of Minneapolis, doubling the power now obtainable at low stages of the river.

The manufacturers to construct the reservoirs.—Provided that the right could be obtained to the lands liable to overflow, which are of little value, and permission could be secured from the government, it appears highly to the future interests of the manufacturers of Minneapolis to carry out the reservoir plan themselves. The following calculation will not bear a rigid mathematical criticism, but is sufficient to illustrate the point:

The cost of construction of the seven dams proposed by the government is estimated at about $400,000. The extent of flowage of entered land was stated by Major Allen, in his report of January 15, 1878, to be probably not more than 2,500 acres, consisting, so far as could be ascertained, of hay meadows and wild rice fields of small value. Setting the very high price upon this land of $10 per acre, the total would be $25,000. Suppose the cost of maintenance and attendance to be $20,000 per annum, certainly a large estimate, and we have this result:

Cost of construction	$400,000
Cost of flowage	25,000
Total	425,000
Interest at 6 per cent	25,500
Maintenance and attendance	20,000
Total per annum	45,500

With the present improvements, and an average head of about 25.5 feet used, there is obtained in round numbers 13,000 horse-power at the mills, and no more can be realized at a low stage of the river without increasing the average head. Suppose it to be increased to 50 feet, which is probably all that will be done for some time. Then assuming a simple proportion, there would be 22,000 horse-power obtained, and no more, without having difficulty in low water.

Supposing a flow of 12,000 cubic feet per second to be maintained throughout the year, at an average head of 50 feet, it would give, with an efficiency as low as 66.6 per cent., 45,000 effective horse-power. The difference, 23,000 horse-power, is the amount of power practically gained by the introduction of the storage system, supposing a head of 50 feet to be used. A horse-power is valued at $10 per year at Minneapolis. According to this estimate the value of the increase of power rendered available throughout the year would be $230,000 per annum. The yearly expense of the reservoirs, $45,500, is a small item in comparison.

The system of natural reservoirs takes to a great extent the place of the artificial ones proposed, and were it not for them the river would be like some of its tributaries, extremely low in severe winters and in drouths. There is no difficulty from backwater, the effect of high water in the river being to increase the head on the wheels.

Difficulty from ice.—Sometimes damage is caused to the dams in the breaking up of the ice, and at one time there was a jam in which the ice piled up 16 feet high and then came down over the falls. There is less danger to the dams when the ice goes out with a full stage of the river than when the water is low. Since the breaking away of a part of the dam, the water-power companies have united in the spring in cutting a channel through the ice about 100 feet wide and 2 or 3 miles long down to the falls. Through this channel the ice passes down without trouble. If the ice is soft at Minneapolis, and liable to pass out as soon there as above, then the channel is omitted. The cost of this work is $2,500 or $3,000.

DETAILED DESCRIPTION OF THE IMPROVEMENTS.

Rates of lease.—The water-power at Minneapolis has been estimated in terms of a unit called a "mill-power", which is equivalent to 75 effective horse-power. The rate of rental is the same with both of the water-power companies, viz., $750 per "mill-power" per annum, or $10 per horse-power. The usual method pursued with the Minneapolis Mill Company is for the manufacturer to buy the land and rent the power from the company.

The Saint Anthony Falls Water-Power Company fixes its rents according to the power used, and if the head is increased then the rent is increased proportionately. Of course some consideration must be taken of the efficiency of the wheels. Regarding the Minneapolis Mill Company, the statement was made that if a lessee increased the head of water at his mill the company would probably raise his rent for one-half the increase of power obtained.

The Minneapolis Mill Company leases its mill-powers for a "two-thirds run", that is, 16 hours out of the 24. During part of the year there is not sufficient water to supply all the mills with a two-thirds run, and the manufacturers have a right to demand a reduction in the rent in proportion to the reduction of the power below that leased. However, during a large part of the year there is more than sufficient water, and as the company allows the mills to run beyond the time stipulated in the lease the manufacturers consider that the one counterbalances the other, and they make no complaint during low water. They agree among themselves about running during low water. Several manufacturers using about equal amounts of power will arrange between them that certain ones shall run their mills during part of the 24 hours, the others taking the remaining time, and thus they divide the flow between them. Nothing of this kind has been done thus far upon the east side of the river, as it has not been fully developed.

The agent of the Minneapolis Mill Company is Mr. H. H. Douglass, of Minneapolis. The agent of the Saint Anthony Falls Water-Power Company is Mr. S. H. Chute, of Minneapolis, east district.

IMPROVEMENTS OF THE SAINT ANTHONY FALLS WATER-POWER COMPANY, ETC.

The dam runs across the east channel about 360 feet above the crest of the falls; then along the side of Hennepin island to its upper end; then diagonally up to the center of the west channel, where it is joined by the dam of the Minneapolis Mill Company on the west side of the river. Up to the head of Hennepin island it is a high dam, never overflowed by high water, and forms really a basin in the east channel from which the water is drawn to the mills. The head of water directly at the dam is from 16 to 20 feet, varying with the stage of the river. Main street runs along the east bank of the east channel. At the dam it is directly at the river-bank, which is here perhaps 20 feet high. Back of the street the bluff rises rapidly.

The mills supplied from the east channel are, with two exceptions, either at the dam or else facing on Main street. The exceptions are a furniture factory, on Hennepin island, and the Northwestern Fence Works, some distance back from Main street, on Third avenue south.

Methods of using the power.—There are two classes into which the various ways of taking the water might have been divided previous to the summer of 1881, when the canal was constructed. They are, (1) taking water directly from the dam; (2) taking it from below the dam, either by tunnels or by flumes in the channel of the river. The methods are shown on the map of the place.

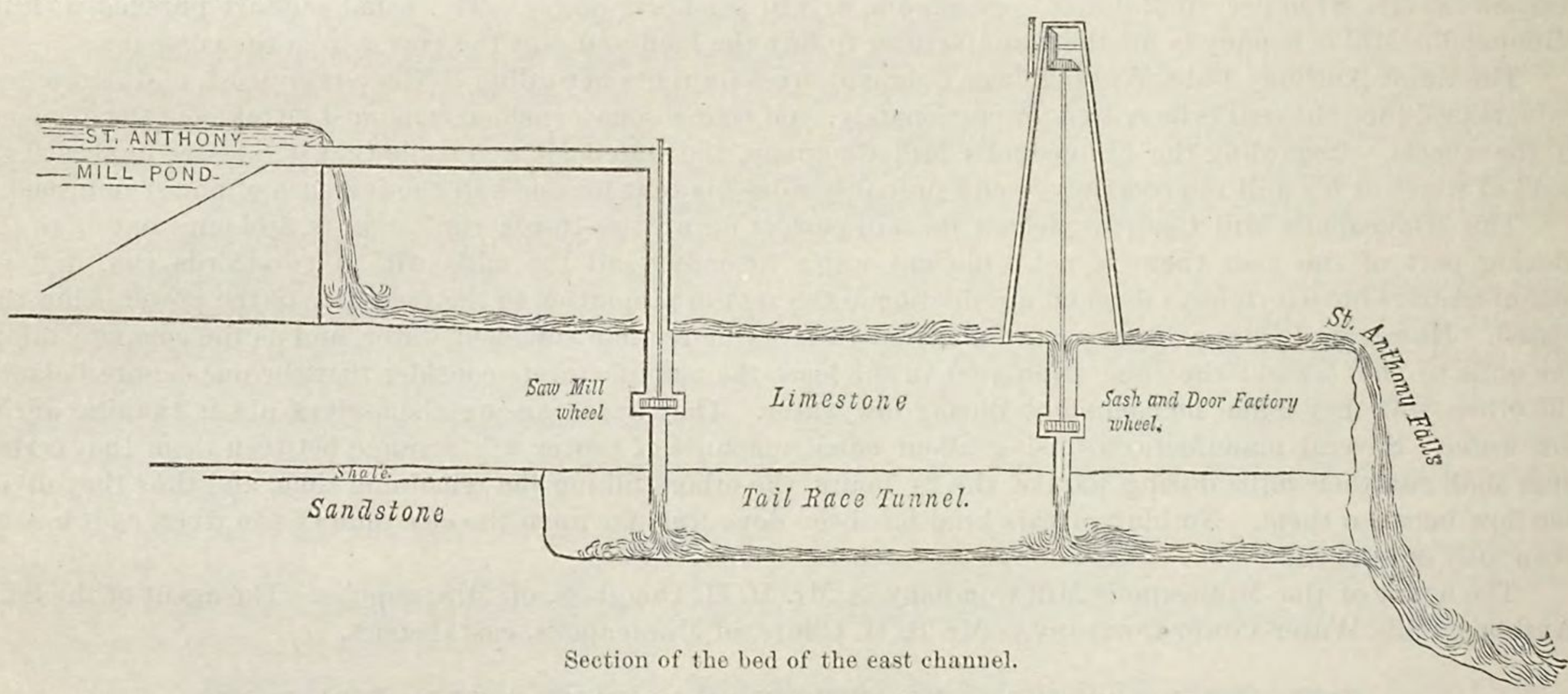
There are five saw-mills directly at the face of the dam, owned by three firms. To these firms there were scaled, during the sawing season of 1879, over 19,500,000 feet of logs. They use not only the head obtainable at the dam, but have run three parallel tunnels below the falls about 350 feet up to the dam, and then have sunk wheel-pits to the tunnels, using them as tail-races. By this means they get an average head of about 35 feet. The wheels are set only part way down in the pits, and draught-tubes are used to get the total effect of the head, as shown in the drawing. Each mill has one wheel, and one tunnel will suffice for two wheels (see map). These saw-mills use 200 horse-power each, and pay no rent to the Saint Anthony Falls Water-Power Company, as they own the power.

Stationed at the dam, and adjoining the saw-mills on the Hennepin island side, is the wheel-house of a set of manufacturing industries of various kinds, stationed at the foot of Nicollet island. It was for the power owned there that the tunnel was dug which came so near proving the destruction of the falls. The project of taking the power at Nicollet island was abandoned, and now it is conveyed by a wire rope of over 1,200 feet length, in two spans, from the wheel at the dam. This wheel discharges through a tunnel similar to those at the saw-mills; 400 horse-power is used, under a head of 35 feet, and no rent is paid to the Saint Anthony Falls Water-Power Company, as the power is owned on the island.

Between the saw-mills and Main street is a wheel, called the Union wheel, which, when visited in the winter of 1880–'81, ran with a head of only 16 feet, obtained at the dam. It gave 130 horse-power, applied to a line of shafting running 600 feet up Main street, and turning the machinery of three machine-shops, an eaves-trough factory, a mattress factory, and, by a branch shaft running across the street, the Union Iron Works. It was the expectation to extend this system in the coming summer so as to use 500 horse-power, probably by increasing the head, making use of the adjoining saw-mill tunnel.

On the east side of Hennepin island, just at the crest of the falls, is a wheel working under a head of about 25 feet, which, by a line of shafting some 150 feet long, connects with a furniture factory using 75 horse-power.

On the east bank of the river, about 100 feet below the crest of the falls, is a wheel, under a head of 25 feet, supplying 75 horse-power to the North Star flouring-mill, on the other side of Main street, by an underground shaft about 125 feet long. The water is carried to the wheel through a wooden flume leading from the bed of the river above the falls.



Section of the bed of the east channel.

Directly over the most eastern one of the three tunnels acting as tail-races for the saw-mills, and about 30 feet below the bridge leading to Hennepin island, is a wheel supplying power to industries on the river-bank. It is set in a very peculiar manner, illustrated in the section showing the discharge-tunnel. A pit was sunk through the limestone bed of the river, piercing the roof of the tunnel. Part way down in this the wheel is placed, with a draught-tube to the tunnel, into which the water is discharged. It enters the wheel through the bed of the river above. By this means a head of 20 feet is used and 75 horse-power obtained. This is transmitted by shafting about 90 feet to a tower on the river-bank, and from it, 320 feet up Third avenue south, to the Northwestern Fence Works by means of wire-rope. There is a small feed-mill in the tower, which is also run by this power.

On the northeast corner of Main street and Third avenue south, is the Phœnix flouring-mill. In the winter of 1880–'81 the wheel of this mill was supplied by a tunnel leading from the river, under Main street to the mill. There is, passing under Main street, an old tunnel which was originally intended for a tail race to all the mills. From a point about opposite the dam it runs down 1,200 feet, and emerges in the cliff below. It is at a lower level than the supply-tunnel to the Phœnix mill, and is used by that mill for a tail-race. A bulkhead was built in the tunnel just above the North Star mill, and the water discharged through a short side tunnel into the river just at the falls. The water leaked around the edges of the bulkhead, wearing away the sandstone, and in December,

1880, a portion of Main street fell in, owing to the breaking of the limestone stratum. There is no serious damage anticipated from this however. The head of water used at the Phœnix mill is 25 feet, and 75 horse-power is obtained.

This brings us to the Pillsbury "A" mill, the latest and largest building not only on the east side, but also at the falls. Its erection marks a new era with the Saint Anthony Falls Water-Power Company in the improvement of its power. Activity has been renewed, and more attempts made to take advantage of the opportunities of the place.

The Pillsbury "A" mill has been already alluded to as the largest flouring-mill of this great milling center. Mr. J. K. Neftel, the special agent on milling, states that the mill has a capacity for turning out 5,000 barrels of flour per day. It stands at the southeast corner of Main street and Third avenue south; a blue limestone building, 115 by 175 feet, and 6 stories high above the street. Mr. C. J. A. Morris, the engineer of the Saint Anthony Falls Water-Power Company, stated that the intention was to make 3,000 or 4,000 barrels of flour per day. The mill engaged from the Saint Anthony Falls Water-Power Company 750 horse-power under 50 feet head of water, but it was thought probable that more would be required.

Hydraulic canal.—Up to this point nothing has been said about the water-power canal. This was being constructed when the place was visited in the winter, and again in the summer of 1881. It is part of a systematic plan of improvement now taken in hand for utilizing the power on the east bank.

The Saint Anthony Falls Water-Power Company owns a large amount of land along the river below the falls, extending as far down as Eleventh avenue south, and it is the intention to carry the water through this land by the canal, supplying mills, which can tunnel out through the cliff to the river for tail-races, much as is done on so large a scale at Niagara falls. The company also, in the winter of 1880–'81, excavated a tail race 800 or 900 feet long from the foot of the falls down the flat between the east channel and the cliff. By running their tunnels into this, mills can obtain a head of 50 feet, as has been done by the Pillsbury "A" mill. The tail-race is 15 or 20 feet wide, averages 10 feet depth, and was excavated out of earth and masses of limestone broken from the falls in past years and piled in every direction.

The plan proposed for the canal was to start from just above the dam and to carry it under Main street in two arched masonry conduits down to the company's land, and then as an open canal through it. This has been calculated with a width of 50 feet and a slope of 1 in 400. Mr. Morris states that a head of from 68 to 70 feet of water would be obtainable on the lower portion. One of the conduits was in process of construction in the summer of 1881, with a width of 14 feet, and was being built in apparently a very substantial and workmanlike manner. From this canal a short inlet was to lead to the two wheel-pits of the Pillsbury "A" mill, and from these two tunnels carry the discharge-water into the new tail-race, giving a head of 50 feet.

It is probable that the Phœnix mill, North Star mill, and others for which water has been let through the dam to the river below, will now change and take water from the new canal.

The following table gives, as nearly as could be ascertained, the power to which each manufactory on the east side is entitled, and the head used:

Power controlled by the Saint Anthony Falls Water-Power Company—Power used on east side.

Nature of manufacture.	Name of factory.	Number of horse-power to which entitled (effective).	Average head, in feet.
Flouring	Pillsbury "A" mill	*a* 750	50
Five saw-mills		1,000	35
General manufactories on Nicollet island		400	35
Iron works	Union Iron Works	*a* 130	16
Three machine-shops			
Eaves-trough factory			
Mattress factory			
Flouring	Phœnix mill	75	25
	North Star mill	75	25
Sash and door factory	Northwestern Fence Works	75	20
Furniture factory		75	25

a See description in text.

According to this table there is 2,580 effective horse-power in actual use on the east side of the river under an average head of 34 feet, but changes are continually being made. Assuming that 2,580 horse-power is used under the several heads given in the table, and that the efficiency is two-thirds, then a flow of 1,000 cubic feet per second is required. The fact probably is that much more than this is used, but the power might be obtained with this volume of water. If the Saint Anthony Falls Water-Power Company should secure the right to one-half the total

flow of the river, then it would have at an ordinary low stage 2,000 cubic feet of water per second more than is now used from the east channel. This surplus, under a head of 50 feet, would give 11,345 theoretical horse-power. With the reservoir system applied, there would be throughout the year a surplus of 5,000 cubic feet per second, and, under a head of 50 feet, 28,363 theoretical horse-power, besides what is already in use from the east channel. If the head under which the present manufactories work is increased to 50 feet, then they will require less water for the same power, and hence the amount of water available for other mills will be increased.

With the large number of mill-sites owned by the Saint Anthony Falls Water-Power Company, the new canal conducting the water to them, and this surplus flow of the eastern part of the river, it is apparent that an immense development is in store for the water-power of east Minneapolis. It was proposed in the winter of 1880–'81 to run a short line of the Saint Paul, Minneapolis, and Manitoba railroad from Saint Paul which would pass by the land owned by the water-power company, and cross the river diagonally below Hennepin island (*a*). Side-tracks would undoubtedly be built to the mills, increasing very much the facilities of trade.

THE FARNHAM & LOVEJOY POWER. (*b*)

The relations of this to the other companies have been already described in treating of the legal conditions of the power. Only two establishments are run from their site. These are their own saw-mill, working under a head of 22 feet and using 300 horse-power, and a paper-mill, which has bought 250 horse-power from them, under a head of 25 feet. These mills are situated on the west side of Hennepin island, at the foot of the Farnham & Lovejoy mill-pond, which averages 150 feet in width, is 1,175 feet long, and is formed by a wing-dam running along the side of the island.

The mills discharge into the west channel below the falls. A canal could be run down the west side of the island on the property, giving a head of from 30 to 35 feet at the mills. All the water entering the mill-pond has to pass over or through the dams of the two water-power companies.

MINNEAPOLIS MILL COMPANY.

This company's dam starts from the west bank, half-way between Fifth and Sixth avenues, and runs straight out into the river 400 feet, to the head of the government apron; then it turns and runs up-stream, uniting with the Saint Anthony Falls Water-Power Company's dam in the center of the channel. The crest of this dam at the lower portion is above high-water mark, and a mill-pond is formed, connected by slack-water with the basin of the Saint Anthony Falls Water-Power Company. From this pond at the end of the dam a canal starts. It is 80 feet wide at the head, but soon narrows to 55 feet, its regular width. For a distance of 345 feet it runs at an angle of about 30 degrees with the river, but then bends and runs parallel with the river for 600 feet. The depth is greatest at the bend, diminishing toward each end, and averages about 12 feet. From this canal most of the manufactories are supplied with water.

Methods of using the power.—There are the following four methods in use of taking and disposing of the water:

1. Taking the water directly from the pond, and discharging directly into the bed of the river, as is done by the row of seven saw-mills situated at the dam.

2. Taking the water directly from the pond and discharging into a tunnel which leads below the falls, as is done by the city water-works and one saw-mill.

3. Taking water from the canal and discharging into the river either by an open cut or by a tunnel, according to the side of the canal from which the water is taken.

4. Taking the water directly from the river at the brink of the falls. This was done only by one cotton-mill upon Upton's island. By far the greater part of the power is obtained from the canal.

The head used varies from 12 to 48 feet, averaging about 30 feet. The only mills using a head of 12 feet are the seven saw-mills, which have taken only the head afforded by the dam; but in the winter of 1880–'81 a tunnel was being driven, similar to the tunnels on the other side of the river, from below the falls up to the dam, and three of the mills were to discharge into this, getting from 30 to 35 feet of head. It was the expectation to excavate another tunnel for the other mills. These saw-mills were bought out by the Minneapolis Mill Company, as they had too much control of the water. None of the other mills, except the cotton-mill, have less than 25 feet of head.

The situation is one of the best possible for the location of manufactories. Fifth, Sixth, Seventh, and Eighth avenues lead down to the mills, and with the streets running parallel with the river afford every facility for traffic. The system of railroad tracks is also very complete. Three side-tracks run between the mills and the river, on a trestle, and cars can be brought directly to the rear of the mills situated on that side of the canal. The canal itself is planked over, forming a street between the mills, and above this are three elevated railroad side-tracks, passing in front of the mills just mentioned. On the land side of the canal are numerous tracks, running to the remaining mills. Two of these tracks pass directly through the large Washburn "A" mill, the second in size at the falls.

a A fine stone bridge for this line is now being built (August, 1882), as shown on the map.

b Since the writing of the report this power has been purchased by the Saint Anthony Falls Water-Power Company.

The depot and termination of the Minneapolis division of the Chicago, Milwaukee, and Saint Paul railroad is less than 2,000 feet distant. By means of these tracks there is every facility for the rapid handling of large amounts of material.

Power controlled by the Minneapolis Mill Company.—The following table gives the head of water and the power used in the winter of 1880–'81 by the different manufactories, as kindly stated by Mr. H. H. Douglass, the agent and engineer of the Minneapolis Mill Company:

Kind of mill.	Name of establishment.	Number of horse-power to which entitled (effective).	Average head, in feet.
Flouring	Washburn "C" mill	900	35
Do	Washburn "A" mill	700	37
Do	Crown Roller mill	525	27
Do	Pettit mill	450	37
Do	Standard mill	413	27
Do	Washburn "B" mill	375	35
Do	Northwestern mill	375	35
Do	Pillsbury mill	300	32
Do	Palisade mill	300	45
Do	Anchor mill	300	27
Do	Empire mill	263	30
Do	Excelsior mill	263	32
Do	Minneapolis mill	225	32
Do	Galaxy mill	225	37
Do	Humboldt mill	225	37
Do	Zenith mill	188	37
Do	Model mill	150	27
Do	Dakota mill	150	27
Do	Union mill	113	27
Do	Arctic mill	75	32
Do	Holly mill	75	28
Do	Cataract mill	75	28
Saw-mills	Minneapolis Mill Company's saw-mills. No. 1	300	12
	No. 2	300	12
	No. 3	300	12
	No. 4	225	12
	No. 5	375	12
	No. 6	300	12
Saw-mill		338	27
Paper-mill		225	35
Woolen-mill	North Star woolen-mill	150	27
Machine-shop		150	27
	City water-works	150	27
Wheel running the elevated railroad		75	32
Cotton-mill	Minneapolis cotton-mill	75	20

Four of the flouring mills—the Excelsior, the Pillsbury, the Minneapolis, and the Empire—as also the Minneapolis cotton-mill, were destroyed by fire on December 4, 1881. The total number of horse-power given in the table is 9,628; and the average head, exclusive of the row of saw-mills, is 30 feet. Of this power Mr. Douglass states that about 1,875 horse-power is not owned by the Minneapolis Mill Company, they having been taken by the members in place of dividends before these were declared.

The Washburn "A" and the Crown Roller mills are the two largest manufactories on the west side of the river. The former had a capacity of 1,500 barrels per day, only using one-half of the building. In the spring of 1881 machinery was being placed to increase the production of this mill to 3,500 barrels, and the Crown Roller, which also used only one-half of the building, was expected to increase its capacity to 3,000 barrels per day.

Assuming an efficiency of two-thirds in the application of the power, then the 9,628 effective horse-power would require a volume of flow of 5,375 cubic feet per second, of which the row of saw-mills belonging to the Minneapolis Mill Company take 1,980 cubic feet per second. These saw-mills were bought by the company in order to control them in the use of water, and they will probably not be run to the detriment of the other establishments; hence, omitting them, the Minneapolis Mill Company requires for the complete satisfaction of all the other manufactories a flow of 3,395 cubic feet per second. This is about 300 cubic feet per second more than one-half the entire ordinary low-water flow of the river. It is evident from this that, unless the head is increased at the different mills, or the system of reservoirs is carried out, equalizing the flow of the river, the Minneapolis Mill Company can make very little further development except for a full stage of the river. If a flow of 12,000 cubic feet per second were maintained throughout the year, they would then have beside the power now in use (including the saw-mills) a surplus flow of about 600

cubic feet per second, and if the head at the saw-mills is increased to 30 feet this surplus will be somewhat increased. This is on the supposition that the company is entitled to half the entire flow of the river. A surplus of 1,000 cubic feet under a head of 50 feet would give 5,670 theoretical horse-power, and represents about all the surplus power which would be available for every day of the year, after the construction of reservoirs.

By an increase of head of the mills now working the surplus power could be very much increased in amount. The channel of the river below the falls could be excavated next to the west bank, as has been recently done at the east shore, and a head of 50 feet or more made available directly at the dam. It would be possible to start some distance down the river and run a large tunnel in the bank under the mill-sites, using it as a tail-race for all the mills. By this means a head of fully 70 feet could be obtained at all the locations. If the head were increased, then there would be surplus power to warrant the proposed extension of the canal. The Minneapolis Mill Company owns land for half a mile down the river, and the canal could readily be continued through this land. Assuming that the company has a title to one-half the entire flow of the river, and that a uniform head of 50 feet is used, then with an efficiency of two-thirds there would be a surplus power over what is now in use of 1,715 effective horse-power with the ordinary low flow, and of 13,055 effective horse-power with the average flow resulting from storage-reservoirs. If a uniform head of 70 feet were used, then the surplus power under the two conditions of flow would be, respectively, 6,255 and 22,140 effective horse-power.

It will be seen from these figures that there are yet opportunities on the west side of the river for considerable development, and it must not be overlooked that the figures apply to power obtainable every day of the year, while there are kinds of manufacturing which can afford to stop their wheels during low water, and hence these could be supplied beyond the low-water limit of the power. There are several unoccupied sites which could be supplied from the present canal.

DAMS AND OTHER ENGINEERING CONSTRUCTIONS.

The solid limestone bed of the river makes an excellent foundation for the building of dams. There is a total of about 5,650 linear feet of dam at Saint Anthony falls, of which some 800 feet belong to the government and the remainder is controlled in the interests of the water-power. A large part of this is of old crib-work construction. The entire length of the V-shaped dam, from the east bank to the west bank, is about 3,670 feet.

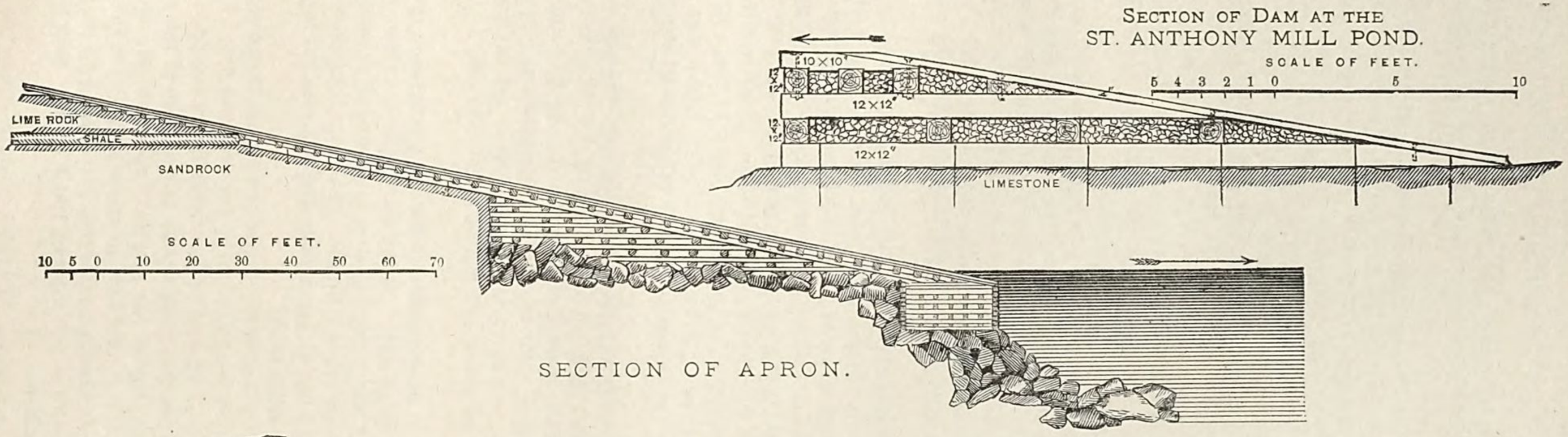
Dams on east side.—The portion crossing the east channel is 440 feet long, and is high enough to be above high-water level. It is constructed of triangular sets of squared timber, planked over on the face. There is no filling or planking on the back. The height varies from 15 to 20 feet.

From this point up to the apex of the dam in the middle of the west channel the construction is of timber crib-work. This was built in 1871, with an average height of 14 feet, at a cost of $25,000. It is about 50 feet broad at the base at the lower end, and from 16 to 20 feet at the upper end. Log cribs filled with stone, the lower timbers bolted 15 or 18 inches into the rock by iron bolts, were used. These cribs were planked over. Five hundred feet of the upper portion was once broken by the ice and carried away. This was rebuilt in a substantial manner of squared pine timbers, about 12 inches square throughout. The construction is a crib-work, with spaces of 2.5 feet, filled with stone. The sleepers were trimmed to fit the rock bed, which is quite even, and each one is fastened down by about six 1-inch iron bolts, let into the rock some 16 inches. The method taken to fasten the bolts was to drill holes in the rock one-half inch larger in diameter than the bolts themselves. These were filled with pine plugs, and then the iron bolts were driven hard into them. As the other dam failed owing to the ice wearing out the planking and then breaking up the unprotected crib-work, the new dam was made specially strong in this respect. The crest, 4 feet wide, is formed of pine timbers, 10 inches square, laid close together in the direction of the current. They are notched to fit the upper course of the crib-work, and are bolted to the timbers of that course. They are beveled at the upper ends to fit the inclined back of the dam, which is covered by 4-inch planking, tree-nailed to the timbers. The face of the dam is vertical and without an apron.

The dams from both sides of the river formerly met in a point very near the upper extremity of the limestone ledge, and there was apparent danger of its being undermined and the dam giving way. Accordingly a crib-work dam 100 feet long was built across below the point, and the latter was removed.

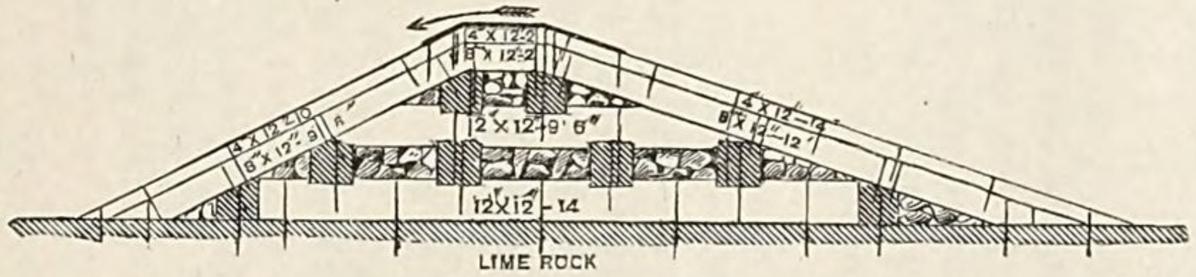
Dams on west side.—From the apex down to the west bank the dam is a log crib-work bolted to the bed of the river, and covered with 4-inch planking. It is about 60 feet wide at the base at the lower end, where the head of water is 12 or 15 feet, and narrows toward the apex as the head becomes less. The water never falls over the crest except at the upper portion, unless the river is extremely high.

Along the row of saw-mills the Minneapolis Mill Company was building in the winter of 1880–'81 a substantial stone dam behind the old crib-work dam. It is constructed of the Minneapolis limestone, rough-dressed, with regular coursing. The face is vertical; the back has a straight batter of about 0.37 in 1. The base is 10 feet wide, crest 3 feet across, and height 19 feet. A few iron bolts were let through the lower courses into the bed of the river as an extra precaution, although the dam is stable in itself. The structure was built in sections. The old dam leaked to some extent, and in order to exclude all water from the foundations a small coffer-dam was built around each section, about 2 feet distant from it. Small posts of scantling were set into the bed about 4 inches, and 2-by 4-inch scantlings spiked to them. Then against these were driven sheeting piles of 1-inch boards, beveled at the



SECTION OF DAM AT THE ST. ANTHONY MILL POND.

SECTION OF APRON.



SECTION OF UPPER ROLLING DAM.

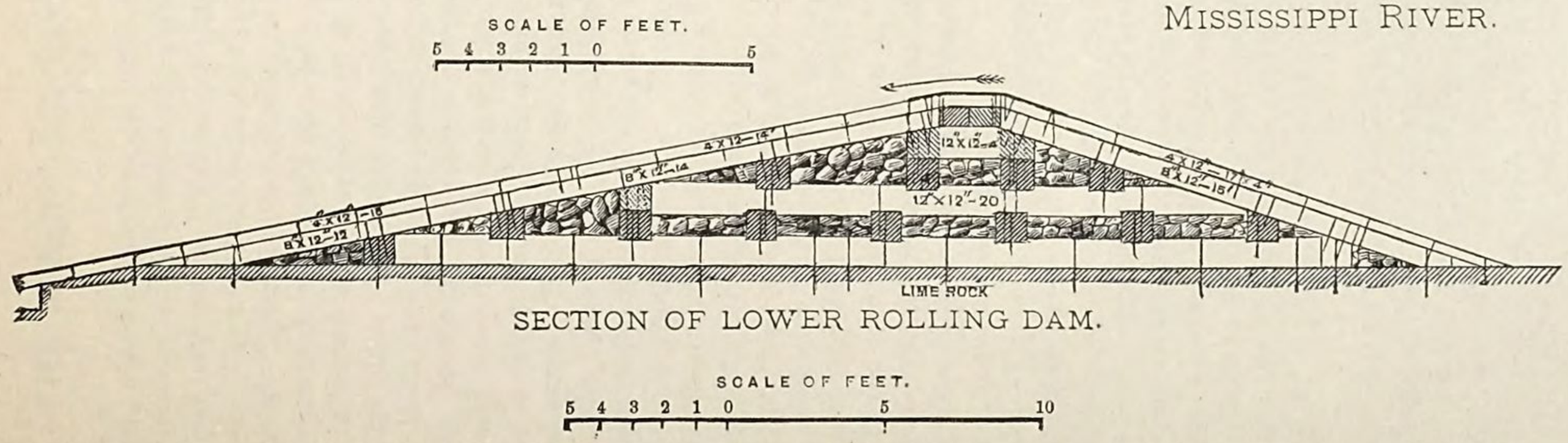
VARIOUS

ENGINEERING CONSTRUCTIONS

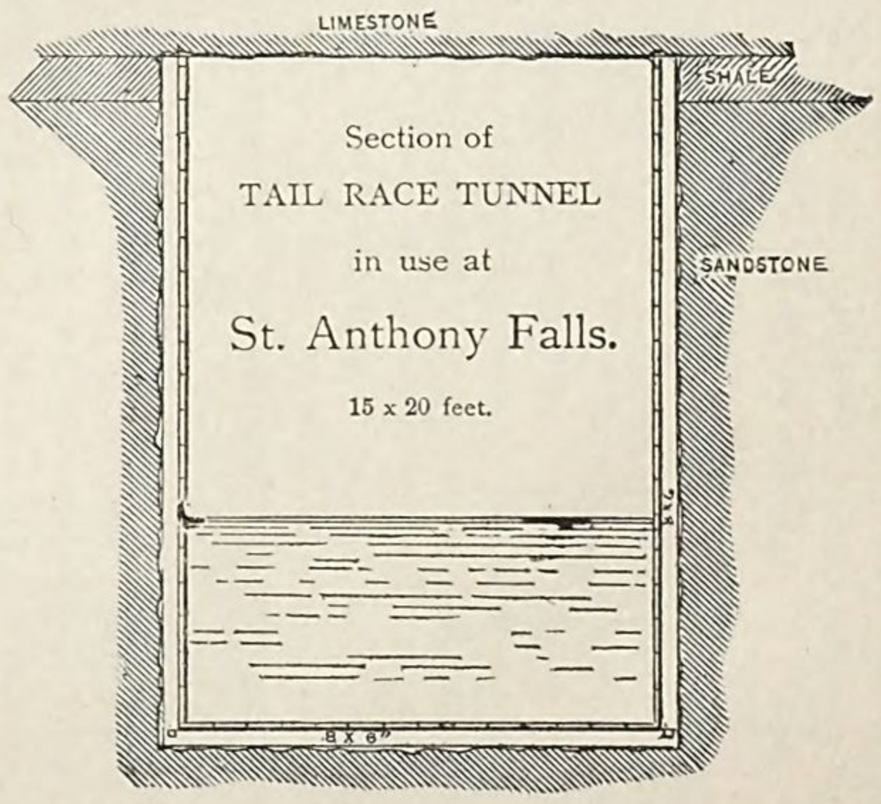
AT

ST. ANTHONY FALLS,

MISSISSIPPI RIVER.



SECTION OF LOWER ROLLING DAM.



ends so that they would crush down and fit accurately to the bed-rock. About 1 foot inside of this was built another similar construction, and the intervening space was tightly packed with decayed horse-manure, which the engineer claimed was fully as good as, if not better than, earth for the purpose.

Roller-dams.—The two dams built by the government between the two sides of the V-shaped dam have been already alluded to. Their object is merely to keep a body of water over the river-bed above the falls to protect it from the frost, hence they are built low, as rolling-dams, allowing ice, logs, etc., to readily pass over their crests. The lower one, situated at the upper edge of the apron over the falls, is 450 feet long, about 44 feet wide at the base, and 5.5 feet high. The upper one, about 670 feet above, is 360 feet long, about 25 feet wide at the base, and 4.5 feet high. Both these dams are constructed of 12 by 12 and 8 by 12 inch timbers, bolted and notched together, as shown in the drawing. The crest is protected by a plate of iron bent over to fit the face and back, which are both inclined, and covered with 4-inch planking. The back of the lower dam has the same slope as the apron over the falls, and is in fact merely a continuation of its surface at the same angle.

Government apron.—The government apron is a very extensive construction built entirely over the falls in the west channel. The cause which led to building the apron has been already given. The main portion is 400 feet long, with an inclination of about 11.5 degrees from the horizontal, and is 245 feet wide in horizontal projection from the crest of the roller-dam to the foot. This makes the total fall 49.75 feet. At the end where the apron abuts on Hennepin island there is an additional apron 215 feet long, built in three planes, to protect the shore of the island. The construction is shown in the drawing.

The limestone ledge was stepped to receive stringers, and on these the timber facing was laid. When the sandstone was reached it was smoothed down, and sleepers were laid on it in the direction of the current; upon these the stringers were laid. At the base of the falls a crib-work of logs and squared timbers was laid, and the stringers and facing were continued upon it. At the foot the apron rests upon a timber crib 20 feet wide and 10 feet high, built of squared timbers laid close at the face and back. The bed at the foot of the apron is protected by heavy stone, thrown in loose. At the western end of the apron is a sluice-way, 6 feet wide and 346 feet long, for the passage of logs down-stream.

Concrete dike.—The course of this is shown on the map, and the causes which led to its construction by the government have been set forth in treating of the geology of the falls. The total length is 1,870 feet, and the cost was about $212,000. As previously stated, the dike consists of a solid wall of concrete 38 feet high and 4 feet thick, cemented to the lower edge of the limestone strata, and extending into the bed of sandstone. In the construction a shaft was first sunk on Hennepin island, and the tunnel driven from it in both directions under the limestone. The wall was built up in sections as the tunneling progressed. The lower portion was made wider so as to allow the leaving of a passageway for the workmen and materials, and a space was also left between the under surface of the limestone and the top of the wall for another passageway. Under the lower passageway a drain was left in the concrete covered by a plank. Afterward the two passages and the drain were all filled with concrete tightly rammed in.

Tunnels.—These are a peculiar feature in the improvements at Minneapolis. The position of the soft sandstone underlying the hard layer of Trenton limestone permits the excavation of these underground tail-races with great readiness. They are dug out of the sandstone usually with picks up to the limestone, which is used as a roof. The sides of sandstone are left vertical. Thus a rectangular tunnel is made. It is always important to remove the layer of shale, about 15 inches thick, which intervenes between the limestone and the sandstone, because if not there is danger of its falling. In the summer of 1880 a sheet 3 inches thick fell while a tunnel was being excavated and killed three of the workmen. The removal of this shale sometimes requires blasting.

The width is ordinarily 15 feet, and as the tunnel is always excavated to the limestone the depth depends upon the head of water required. Ordinarily the tunnels are 20 feet in height. As there is no special tendency to lateral movement of the rock, there is no necessity of timbering the tunnel as the work progresses, unless there should be a very heavy body of water above, sufficient to force its way through the seams in the limestone to a great extent, but as the sandstone is easily worn by running water it is important that this should eventually be protected. The old method of doing this has been to timber the floor and sides, leaving the limestone roof uncovered, as it merely scales off slightly. Sets made of 8 by 6 inch squared timbers are placed in position and then planked over on the floor and two sides. The disadvantage of this method is that the timbering rapidly decays on the walls where exposed to the air. A better practice now being pursued is to put in a timber flooring, but to build the sides of stone or brick. The new tunnel to the saw-mills on the west side of the river has vertical sides with brick facing 12 inches thick. In a tunnel proposed for the east side, it was Mr. Morris' intention to build the walls of brick with a slight batter.

The cost of running a tunnel is very nearly the same at all places at the falls; for a tunnel with a cross-section of 15 by 20 feet it averages about $10 per linear foot for the excavation, and $1 per linear foot for timbering, where that is used alone.

There is in use now by the manufactories not far from 5,230 linear feet of tunnel, of which 2,730 feet are on the west side and 2,500 upon the east side of the river. There has been, including the excavation for the government dike, at least 1.8 mile of tunnel excavated about the falls of Saint Anthony.

THE RIVER BELOW SAINT ANTHONY FALLS.

When the river leaves its new channel and enters the old river valley at the junction with the Minnesota, it passes from the rock to the soft drift bed which, with two exceptions, characterizes it to the Gulf. Consequently the slope is comparatively uniform and gentle, and there is, as might be expected, no available water-power below the Minnesota river, with the exception of the two places just alluded to; there the river-bed is of solid rock, and accordingly at Rock Island rapids and at Des Moines rapids there are available water-powers.

From the foot of Saint Anthony falls down to the mouth of the Minnesota river the slope is great, and it is possible to construct a dam at Meeker's island, just above the foot of the gorge, where the river is 800 feet wide, and obtain a head of 30 feet, without injuring the power at Saint Anthony falls. In connection with the navigation of the river, it was once proposed to build a dam at this point.

ROCK ISLAND RAPIDS.

These rapids are 896 miles from the source of the Mississippi and 382 miles below Saint Anthony Falls. They are 14.75 miles long, with a total fall in low water of 20.4 feet, giving an average slope of 1.383 feet per mile.

The rapids consist of a series of pools alternating with rapids over rock in place, which crosses the river in a series of dams. These are called "chains", and there are ten such designated on the United States engineer's maps, with the following names: Upper, Smith's, Sycamore, Crab Island, Saint Louis, Campbell's, Winnebago, Duck Creek, Moline, and Lower Chain.

Geology.—The rock forming the bed of the river is Magnesian limestone in place. The river here leaves its ancient trough and bed of soft drift to flow across the country, cutting a new channel in the limestone rock which underlies the soil. Hence the concentration of descent at the rapids and the swell in the uniform curve of the profile of the river, as shown on the curve sheet.

The slope is greatest at the lower portion of the rapids, about half of the total fall occurring in the last 5 miles, and the utilized power is taken there. The Rock Island rapids have long proved a serious impediment to the navigation of the river, and the United States government has been engaged for many years in improving them in this respect. The local officer in charge of the work and of the entire river from Saint Paul to the mouth of the Illinois river, with the exception of Des Moines rapids, is Captain Alexander Mackenzie, to whose kind assistance there has already been occasion to refer. The system used has been to blast out a channel where the chains are, 200 feet wide and 4 feet deep in low water. It is now proposed to increase these dimensions to 400 feet and 6 feet, respectively.

General description.—Beginning at the foot of the rapids, and extending up-stream over 2.5 miles, is the island from which the rapids take their name. It embraces nearly 1,000 acres of land and averages 3,000 feet width. The main channel of the river, through which all vessels pass, is on the north side of the island, while on the south is the south channel or slough, as the subordinate channels are named in the Mississippi valley. The government has taken possession of the island, and is now erecting, on a very extensive scale, an arsenal and manufactories for the War Department. The island is beautifully laid out with a broad central avenue, bordered by rows of trees, and is a place of great interest to the visitor. Colonel D. W. Flagler, major of ordnance, is the commanding officer, and to his kindness this report is much indebted.

Directly at the foot of the rapids, on the northern or Iowa side of the river, is the city of Davenport, and opposite, in Illinois, is Rock Island, both large and thriving cities. About 3 miles above Rock Island city, on the same side of the river and opposite the head of Rock island, is the town of Moline, a corruption of the French word *moulin*, meaning mill. This is a manufacturing center of considerable importance, a specialty being agricultural implements, wagons, etc. Rock Island is connected with the Illinois shore by wagon-bridges at both extremities, and the Chicago, Rock Island, and Pacific railroad, which crosses the river between Davenport and Rock Island (city), crosses the lower extremity of the island. The bridge across the main channel is one of the finest on the river, having railroad tracks above and the highway below.

All manufactories at Davenport, Rock Island (city), or Moline, have, of course, close connection with the through lines of railroad and every facility for transportation.

All water-power improvements, with the exception of three unimportant mills at the upper part of the rapids, are on the south channel in its upper portion. Power is, or has been, used by the manufactories at Moline, and is now used to drive the machinery of the government manufactories at the arsenal.

The first improvement was made at Moline, and hence the power has come to be known, what there is of it, as the Moline water-power. The rather peculiar condition exists of very fine and substantial works, with scarcely any power obtainable from them, owing to the silting up of the head of the channel, and there is an unfortunate disagreement between the Moline Water-Power Company and the government, whereby the use of the power has been to some extent delayed.

History of the development.—To understand this it is necessary to review briefly the history of the improvement. In 1841–'42, Messrs. David B. Sears and John W. Spencer, after obtaining a charter from the state of Illinois, built

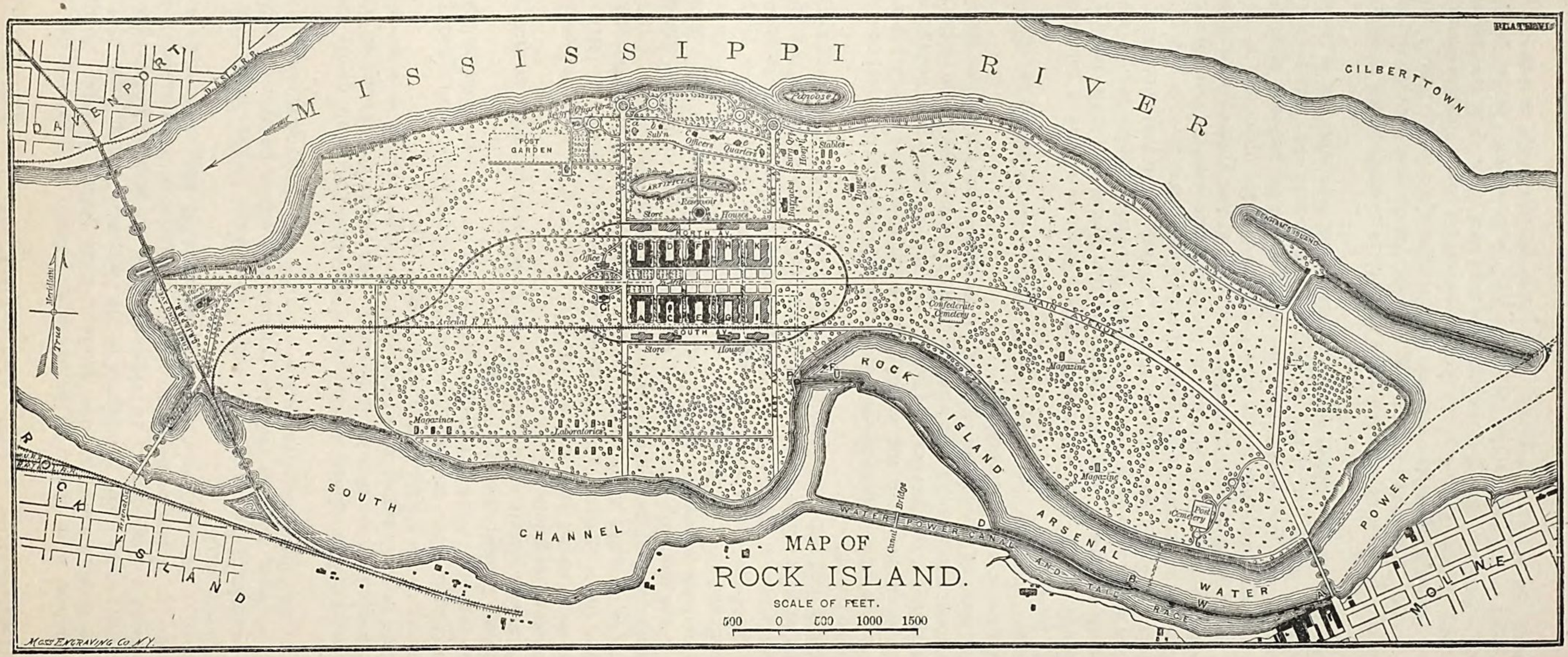


PLATE XVII
MISSISSIPPI RIVER
CILBERTTOWN
DAVENPORT
D.S.P.R.R.
POST GARDEN
Sub'n
Officers Quarters
Stables
Reservoir
Store
Houses
NORTH AV.
MAIN AVENUE
SOUTH AV.
Office
Arsenal R.R.
Confederate Cemetery
Magazine
ROCK ISLAND ARSENAL
WATER POWER CANAL AND TAILRACE
Canal Bridge
Magazines
Laboratories
Post Cemetery
POWER LINE
WATER
SOUTH CHANNEL
CASTLAND
Meridian
True
MAP OF
ROCK ISLAND.
SCALE OF FEET.
500 0 500 1000 1500
MOSS ENGRAVING CO. N.Y.

a dam across the south channel from Moline to the island, and a saw- and grist-mill was erected at Moline. In 1851 the power passed, by sheriff's deed, into the hands of Pitts, Gilbert & Pitts. Finally, owing to failure to pay bonds, the entire property came under the control of Mr. Horace K. White, jr., in 1864. Mr. White held the property as trustee for himself and associates. In February, 1865, the present Moline Water-Power Company, of which Mr. Charles Atkinson, of Moline, is president, obtained a charter with the expectation of buying the water-power and adjoining property; formed the company in December, 1865, and, at the same date, bought the water-power, franchises, and adjoining land.

About this time the question of the use of the power at Rock Island by the government was agitated; and in November, 1865, General Rodman, who was then the commanding officer, addressed a letter to the agent of the water-power company with reference to an arrangement whereby the government could have a partial use of the power.

Contract of the government and the Moline Water-Power Company.—The result finally was that in the summer of 1867 an agreement was made between General U. S. Grant, who was then Secretary of War, and Mr. Atkinson, whereby the Moline Water-Power Company ceded the entire water-power, and so much of the river-bed as was necessary for its development, to the United States, with these conditions:

That the water-power company have the free use of one-fourth of the entire power, and the privilege of renting for a specified time, at the rate of 50 cents per square inch per annum, so much additional power as the Secretary of War may deem it expedient to authorize to be rented.

That the government should develop and maintain the power, and in such a manner as to allow the water-power company to avail itself of its privileges.

That the government should spend $100,000 upon the improvement of the power, as much as was necessary, up to the limit of $40,000, upon the wing-dam; and the remainder upon the extension of the dam on the Moline side, no unnecessary obstruction to be made to the use of the then existing power during the progress of the work, nor any payment of water-rents to be required until the $100,000 were expended.

In view of the above it was mutually agreed that neither the company nor the government should at any time make any obstruction of the water-power as it then existed or should exist when further developed.

The difficulty has been, and is now, the claim on the part of the Moline Water-Power Company that the government has not made good the conditions of the agreement. The chief points of complaint appear to have been that the yearly accumulations of silt in the pool, and also that existing previous to the contract, had not been removed; that the remains of works used in the improvement had not been removed, nor stone excavated in the canal; and that the wing-dam had not been completed. This latter Colonel Flagler is engaged in building, and he hopes by its aid to remove the silt.

Without involving ourselves in the consideration of an interminable amount of correspondence, investigation, etc., over which numerous commissions have sat, and out of which no small amount of annoyance and unpleasantness has been engendered, it is sufficient to state that the power, as it now exists, is practically worthless to the Moline Water-Power Company, without pretending to say whether the government is to blame or the water-power company is simply unfortunate. The head of the channel is so silted up that the manufactories have, with one exception, abandoned their wheels and use steam-power entirely.

The works for the improvement of the power are of government construction and of a most substantial character, as will presently be seen.

Opposite Moline the south channel is 700 or 800 feet wide. There is a bend in this channel below Moline to the northwest, and then south and west. The dam starts from the Moline side at the bridge, and runs down 2,280 feet, nearly parallel with the shore, to a dike, which runs 1,650 feet farther in the same general direction, striking the side of the channel again. It then runs along the shore 2,300 feet to the maximum point of the bend, where a dam about 650 feet long crosses the channel to the Rock island shore. Thus there is formed a pond or pool in the south channel. The space between the dam and dike and the Moline shore serves as a tail-race, which is continued across the neck of land at the bend by a canal, 2,100 feet long and 150 feet wide, excavated in the rock. This tail-race is intended for the Moline manufactories, which took their power at the upper end of the long dam by wheels, situated directly at the foot of the dam, transmitting the power across the tail-race by shafting. The power for the arsenal is taken at the Rock island end of the short dam which crosses the channel at the bend. The wheels are placed at the foot of the dam, and the power is transmitted several thousand feet to the government works by means of wire rope.

Opposite the northern end of the island, in the main channel, is a small island, about 1,000 feet long by 100 feet wide, called Benham's island. A dam, 450 feet long, cuts off the channel between the two islands; and from the upper end of Benham's island a wing-dam runs up stream some 2,400 feet. This is intended to deflect the water into the south channel. Colonel Flagler is engaged in continuing this wing-dam about 1,300 feet farther, at the angle shown in the map. He fears that if it is carried beyond this distance it may interfere with navigation. It is feasible to obtain a head of 4.5 feet at the Benham's Island dam, and Colonel Flagler has a scheme for establishing a gun-forge there, using the water-power. The ore or pig-iron could be floated directly to the place.

Amount of power.—The head of water obtained by the paper-mill at Moline, which is the only one using the power, varies from 3 to 7 feet. Colonel Flagler, who considers the obstruction to the power as merely temporary, and expects eventually fully to restore it, says that the head of water will then be at Moline 6 feet at high water and 7 feet at low water, while on the government wheels it will be 6.8 feet at high water and 7.8 feet at low water. He estimates that the total flow into the south channel will give an average of 3,500 theoretical horse-power, of which, according to the agreement, 875 horse-power will belong to the Moline Water-Power Company, and the remainder, 2,625 horse-power, will belong to the government. This it is the expectation to use at the shops, obtaining from 2,000 to 2,200 effective horse-power. Colonel Flagler attributes the small flow of water into the south channel partly to the Moline chain of rock which crosses the river at its head, and partly to the mud deposit. He hopes, by means of the wing-wall, flood-gates in the Benham's Island dam, and a movable coffer-dam, which can be cheaply constructed, to scour out the deposit from the head of the channel; and then he will cut a channel (shown by the dotted lines) through the rock. With the channel once cleaned out, it is the expectation that it can be kept free from further deposit.

Moline Water-Power Company.—The Moline Water-Power Company owns the Moline shore of the south channel to a point below the end of the long dam; but, with the present improvements, there are only about 17 lots available for power, because the government will not allow the taking of power except from the dam. The following are the manufactories upon these lots supplied with wheels, in their order down stream: Moline Plow Company, lots 1 and 2; Moline Paper Company, lot 3; Deere & Co. (agricultural tools), lots 4 and 5; lots 6, 7, and 9 unsold; Moline Wagon Factory, lots 10, 11, 12, and 13; Union Malleable Iron Foundery, lots 14 and 15.

As before mentioned, all have abandoned their wheels, with the exception of the Moline Paper Company, which uses four 75-inch Dayton wheels, under a head of from 3 to 7 feet. These can not be run under a head of 3 feet, and part of the time steam is used. The manufacturers who leased the power from the water-power company are chiefly heavily interested in the company itself, and hence do not occasion much difficulty to its officers.

Provided the full power is restored, as previously explained, the water-power company could utilize all the surplus from the government wheels, as well as its own power, upon the seventeen lots opposite the long dam.

Further improvement of the rapids for water-power.—There was at one time a scheme proposed for utilizing power at Davenport, on the Iowa side of the river. The plan was to start on the north side of the main channel, at a point just above the Moline chain, and extend a canal along the bank about 3 miles to Davenport. At the upper end it would run across a point of land for perhaps half or three-quarters of a mile, but the remainder of the distance it would be formed by a retaining-wall, built in the river parallel with the shore. The wheels would be set in the river at the lower end of the canal. A head of 5 or 6 feet would be available at the foot of the canal. Major Hoffman, who is connected with Captain Mackenzie's office in Rock Island (city), was employed to report upon the plan. He reported against it, as it would cost from $1,000,000 to $1,500,000, and would be liable to interfere with the navigation. By a continuation of the canal about 3 miles farther up stream, the head available would be increased by only from 1 to 1.5 foot, while the expense would be very much greater.

It is not probable that any power of magnitude can be obtained at Rock Island rapids, except the Moline power, without a very heavy expense. At Moline there is the double advantage of a greater slope, nearly double the average, and a small channel of considerable length, unused for navigation, and admitting of a comparatively inexpensive improvement. The same advantages do not exist at other points.

The Moline water-power is not the only one used at Rock Island rapids. There are three small mills, each with about two runs of stones, at different points above Moline, using undershot wheels, run by the current of the river mainly. They have ordinarily a slight head of about 15 inches, obtained in two cases by wing-dams, and in the other by a dam run across to an island. The wheels work best when the river is 2 or 3 feet above low stage. They have a vertical range of 3 or 4 feet, but are sometimes completely drowned.

Engineering constructions, etc.—The limestone bed of the river forms a firm foundation for the dams.

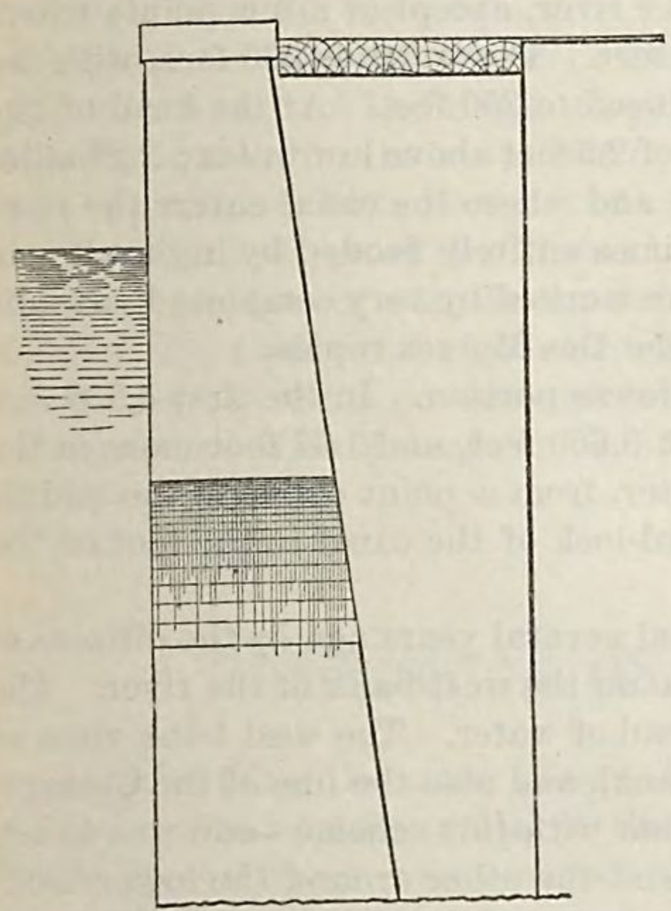
Dam from A to B.—This is built of Joliet limestone, obtained at Joliet, Illinois. The stone is of a light-yellow or buff color, and is extensively quarried for building purposes. It, and the Grafton and Anamosa stones, are the three varieties used in the buildings on Rock Island. The last two varieties are of a light-gray color. Colonel Flagler considers that the Grafton stone is superior to that from Joliet, where exposed to water and frost. The dam is built solid of rough-dressed, regular-coursed masonry. It is 2,280 feet long, 22 feet high at the upper end, and 24 feet at the lower end, 8 feet wide at the base, and 4½ feet wide at the top. At distances of 10 feet are buttresses 3 feet thick, with 11 feet breadth of base. At intervals are openings between the buttresses to pass the water into the penstocks of the mills.

Dike from B to D.—The first 1,750 feet, to the point at which it strikes the shore of the channel, is a very fine specimen of work. It consists of a riprap of stone, excavated from the tail-race, laid around a core of beton. The beton core starts from the rock bed 5 feet wide, and rises about 22 feet, with a width at the top of 3 feet. On each side of this the riprap is laid, 66 feet wide at the base, 14 feet at the top, and 25 feet high. The sides are faced with smooth-laid riprap. Colonel Flagler thinks now that the core was unnecessary, as the small holes in the carefully-laid riprap are silted up sufficiently to prevent all leakage. The remainder of the dike, which extends along the bank to the short dam, is of earth, faced with riprap. The total length of the dike is 4,050 feet.

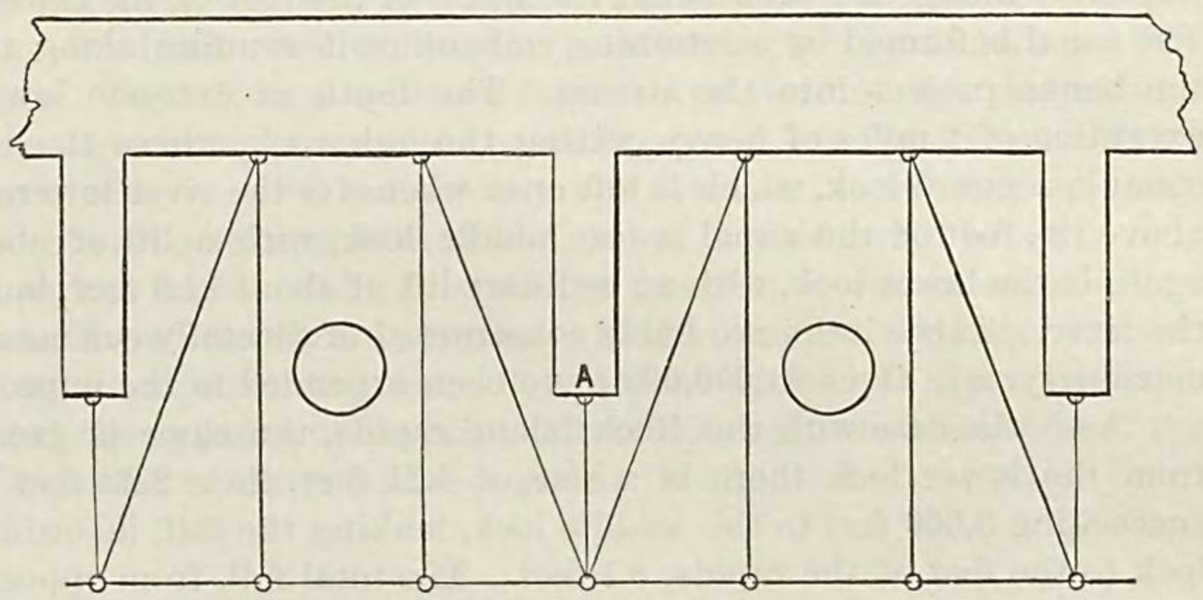
Tail-race canal.—This was excavated across the neck of land to give a discharge passage for the Moline manufactories. The total excavation made is 2,280 feet long, 200 feet wide at the top, 150 feet wide at the bottom, and averages 17 feet deep. The land is rocky, and in some places there was a covering of a few feet of earth, while at other places the rock surface was bare; hence the canal is practically a cut through the solid Magnesian limestone. This was found to be very uneven in nature. In some parts it contained cavities and seams, and then again a very hard, tough variety would be encountered. The most experienced blasters had difficulty in preventing the charges from blowing out through the tamping. Colonel Flagler said he would rather work in solid granite.

Short dam across the south channel.—This crosses the channel at the bend. It is built in much the same manner as the long dam already described, of rough-dressed, solid masonry of Joliet limestone, with regular coursing. The wheels now in use by the government are at the foot of the dam, and it is the intention to set wheels along its entire length. Because of sinking the wheel-pits the foundations were built down into the limestone ledge about 7 feet. The height of the dam proper is 26 feet. The buttresses are vertical at the face, with 8 feet depth and 16 feet between centers. There are 41 openings between the abutments to admit the water to the wheels, and it is the intention to have eventually 40 wheels ranged along the dam, 20 driving the machinery of one line of shops by wire rope and shafting and 20 the other line in the same manner. The plan of the works is an ingenious one, and the part already carried out at the dam is the first step in a carefully arranged scheme. Colonel Flagler is making a remarkably thorough study of teledynamic transmission; and as the writings of former engineers, both of this country and abroad, are in certain respects incomplete in this rather modern method of transmitting power, he is conducting careful experiments with the temporary line of wire rope now in use. The results of his investigations, when published, will be of great value to the engineering profession.

There are now in place at the Rock island end of the dam four 65-inch wheels, of the Houston pattern, which was decided to be the most suitable for a power liable to floating *débris.* These wheels gear upon a horizontal line of shafting running parallel with the dam directly above them, and the wheel-house is built on the dam and buttresses as a foundation wall. A heavy flooring of 14 by 14 inch pine timbers laid close rests upon the buttresses as piers, and on this the machinery is placed. Outside of this a light flooring extends beyond the buttresses 6 feet, arranged so that it can be readily taken up. Overhead is a traveling crane. When new machinery is to be set the light floor can be removed, the machinery carried in and placed by the traveling crane, and the power increased without interfering with the working of the rest of the wheels.

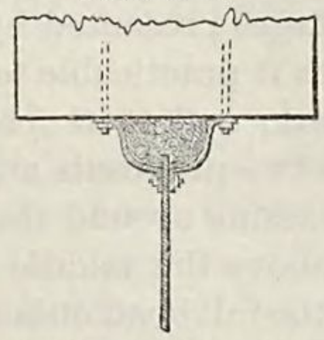


Section of Dam



Plan of Dam and Penstock

Detail at A



Penstock in use at Rock Island, Ill. Designed by Colonel D. W. Flagler.

The buttresses, besides serving as piers for the machinery, also form part of the sides of the penstocks. Owing to the variation in the head of water, a wooden penstock would be alternately exposed to air and water, and subject to rapid decay. On this account Colonel Flagler devised the unique penstock used at the dam. It consists of a heavy oak floor always below the water surface, with sides of one-quarter inch plate-iron. The penstocks are 14 feet by about 16 feet. Four-segment Phœnix columns form the posts which hold the iron plates. These are riveted in between the segments of the columns. The plate which forms the continuation of the side of the penstock beyond the buttresses is fastened to the latter by means of two segments of a Phœnix column, which are bolted to the masonry, as shown in the drawing. The plate is riveted between them, and to prevent leakage the column is filled with cement. The plates are stiffened to resist the thrust of the water by means of buckstays, which are

placed closer toward the bottom, where the pressure is greatest. The columns are stayed to the masonry as shown, by means of the bars fastened to eye-bolts let into the masonry. Colonel Flagler stated that the cost of this kind of penstock did not exceed by more than 30 per cent. the first cost of a good oak one.

DES MOINES RAPIDS.

These are the lowest rapids met in the Mississippi river. They are 114 miles below the Rock Island rapids, and 3 miles above the mouth of the Des Moines river, which enters from the west. The rapids are 11.1 miles long, and in ordinary low water have a total descent of 22.17 feet, or 1.994 foot per mile, while the average slope of the Rock Island rapids is only 1.385 foot per mile. The head of the rapids is at Montrose island, and the city of Keokuk is situated at their foot on the Iowa bank. The rapids are somewhat similar in character and extent to the Rock Island rapids, but they are more uniform, not consisting to so great an extent of a succession of rapids and quiet pools. Previously to improvement by the government they formed a very serious obstruction to the navigation of the river, prohibiting it in low water, while it was possible for light boats to navigate Rock Island rapids at all stages. By excavating a channel and building a canal, navigation has been rendered safe at all stages of the river.

The Des Moines rapids are in charge of Major Amos Stickney, whose office is at Keokuk; and under his direction very fine works have been carried out. No water-power is in use, but there is an opportunity for making available a power of large amount.

Geology.—The geological history of the Des Moines rapids is much the same as in the case of the rapids just described; the river has left its ancient trough, and is now wearing a new one through the rock. The bed throughout the length of the rapids lies in what are known as the division beds, separating the Keokuk limestone from the underlying Burlington limestone. These division beds consist of cherty layers alternating with layers of hard gray limestone, and average about 40 feet in thickness. The Keokuk above contains the celebrated "geode bed". The dip of the strata is toward the southwest, and at the rapids the inclination of the river-bed is nearly the same as this dip. Perhaps it is on this account that the slope is more uniform than at Rock Island rapids.

Navigation.—In improving the navigation of the rapids a channel was blasted out of the bed of the river, along the west shore from Montrose island, 3.27 miles long, down to the little village of Nashville. This channel is 200 feet wide, and has 5 feet depth of water in a low stage of the river. From the lower end of the channel a canal was built along the west bank, 7.6 miles, to the foot of the rapids, entering the river again at the city of Keokuk. The canal is formed by a retaining embankment running along the bed of the river, except at a few points where the banks project into the stream. The depth at extreme low water is 5 feet. The width is 300 feet, with the exception of 2 miles of heavy cutting through rock, where the width is reduced to 250 feet. At the head of the canal is a guard-lock, which is left open whenever the river lowers to a stage of 2.5 feet above low water; 2.28 miles above the foot of the canal is the middle lock, with a lift of about 13 feet; and where the canal enters the river again is the lower lock, with an ordinary lift of about 11.5 feet, but it is sometimes entirely flooded by high water in the river. These locks are finely constructed of carefully-cut masonry, and are worked by very complete hydraulic machinery. (*a*) Over $4,000,000 have been expended in the improvement of the Des Moines rapids.

As is the case with the Rock Island rapids, the slope is greatest in the lower portion. In the first 4,800 feet from the lower lock there is a rise of 4.21 feet, then 2.22 feet in the next 3,600 feet, and 1.67 foot more in the succeeding 3,600 feet to the middle lock, making the fall, in ordinary low water, from a point opposite the middle lock to the foot of the rapids, 8.1 feet. The total fall, from opposite the guard-lock of the canal to the foot of the rapids, is 18.31 feet.

Plans for improvement of the power.—The plan which was actively proposed several years ago by the citizens of Keokuk was to avail themselves of the advantages presented by the ship-canal on the west bank of the river. The rapid fall at the lower part of the rapids makes it practicable to get a good head of water. The west bank rises as a steep bluff, close to the river for the most part; and at its foot is the ship-canal, and also the line of the Chicago, Burlington and Quincy railroad. There were two proposals made in connection with this scheme—one was to tap the ship-canal by two hydraulic canals, one passing around the middle lock and the other around the lower lock; the other was to run a hydraulic canal from above the middle lock, on the land side of the ship-canal, all the way down to its lower end at Keokuk, there using the full head obtainable, averaging 16 feet. This scheme was reported on by Mr. D. C. Jenny, a civil engineer. There was much opposition to it, and a commission of United States engineers, appointed to consider the matter, decided against it, on the ground that it would interfere with navigation. The tendency would be to draw down the level in the upper level of the canal, increase the current, and, possibly, draw in sediment. It does not seem probable that water-power will ever be used from the ship-canal.

The following points concerning the proposed improvement are taken from Mr. Jenny's report: He states that, with the present condition of the structures for filling the canal at the upper end, there might be 700 theoretical horse-power developed, and by suitable improvements this could be increased to 2,000 horse-power without detriment to the canal or to its use for navigation. The two plans, viz., of a long hydraulic canal around both locks

a A full description of these locks, etc., by Mr. R. R. Jones, Major Stickney's assistant, will be found in the *American Engineer* of March, 1881.

and of a short one around each of the locks, are discussed. By the first all the power would be developed at Keokuk, with an average head of 16 feet (the fall is about 18 feet); and by the second plan the head would be about equally divided at the two locks. The backwater sometimes completely floods out the lift of the lower lock, and during a large part of the year reduces it considerably. This may be caused by high water in the river itself, or may happen during a low stage accompanied by a very high stage of the Des Moines river 3 miles below, which has been known to back the water up on the Des Moines rapids nearly 2 miles above Keokuk. On this account the head of water at Keokuk from a hydraulic canal would be subject to a range of at least one-half its amount, and the power would be very much interfered with during high water, while by the second method the portion of the power used at the middle lock would be less liable to obstruction.

To obtain 2,000 theoretical horse-power under a head of 16 feet Mr. Jenny calculates would require a flow of about 1,080 cubic feet per second, which, if a long canal were used, would require the latter to be 85 feet wide on the bottom, 5 feet deep, with side slopes of one-half to one, and a slope of 0.7 foot per mile. It was proposed to tap the government canal about 600 feet above the middle lock, pass under the railroad, and continue down the west side of the railroad for the entire distance, using the canal embankment for the railroad. The hydraulic canal would occupy the part of the government canal where it exceeded 300 feet in width from the east side. The expense would be very heavy, involving the moving of the railroad tracks, large rock excavation, a protecting wall to the embankment along the government canal, and possibly a vertical retaining-wall along the bluff. It could not be less than $150,000.

If the second plan were used the cost would not be more than one-third as great. To obtain the flow of 1,080 cubic feet per second in the upper level of the government canal, Mr. Jenny proposed to excavate a sluice-way around the guard-lock, with a bulkhead at the upper end to control the passage of water; also to run a wing-dam up-stream 600 or 1,000 feet from the head of the retaining-wall of the canal, to deflect a greater body of water into it and to prevent the drawing down of the level in low water by the mills. To obtain this volume of water through the government canal, 250 feet wide by 5 feet deep, would require a current of 0.6 mile per hour, and a declivity in the surface of 6 inches in the distance to the middle lock. In other words, the level would be drawn down 6 inches at that point. If the wing-dam were extended it would give a velocity of 1 mile per hour; then, with 5 feet depth in the canal, there would be 3,400; with 6 feet, 4,000; and with 7 feet, 4,600 theoretical horse-power. It was Mr. Jenny's opinion that a current of 0.6 or even 1 mile per hour would not be objectionable for navigation.

Development on the east side of the river.—There is a chance for a development of water-power on the east, or Illinois, side of the river, opposite Keokuk. There the bluff recedes, leaving a broad bottom-land, across which a slough or old deserted channel of the river passes. By building dikes on each side of the slough, using it for a hydraulic canal, and building a wing-dam 2 or 3 miles up-stream, it would be possible to get a head of 10 feet. There is plenty of room for the utilization of power, and probably it could be done without detriment to navigation in any way; but there is little prospect of carrying out a scheme attended with such expense as this would involve.

There are places on the Illinois bank farther up the rapids where it would be possible to obtain a small head of water by means of wing-dams, and the bluffs recede sufficiently to permit its utilization, but the concentration of fall at the foot of the rapids makes that the place to improve the power, if it is done at all. It seems probable that unless use of the government canal is permitted the expense of development will prevent the utilization of the water-power of Des Moines rapids, at least until the value of water-power is greater in the west.

DISCUSSION OF THE TRIBUTARIES OF THE MISSISSIPPI.

In describing the water-power of these streams it is thought best to begin at the upper waters and describe each one, with its tributaries, in the order in which it is met in passing down the main river. To Mr. Dwight Porter, special agent, were assigned all the western tributaries from the mouth up to the Turkey river, in Iowa, and these will be omitted in this report. Exclusive of the large tributaries—the Ohio, Missouri, Arkansas, and Red rivers—the principal water-power rivers are the Des Moines and Iowa rivers in Mr. Porter's section, and the Illinois, Rock, Wisconsin, Chippewa, Saint Croix, and Minnesota, which are about to be described. With the limited time at disposal it was impossible to investigate exhaustively each small stream, and therefore some discrimination has been necessary in deciding where to devote the time at command. The table of tributaries contains a complete list of all tributaries of the Mississippi of over 500 square miles drainage area, and from it may be gained some idea as to their physical characteristics.

RIVERS ABOVE THE CROW WING.

These are in the undeveloped region of northern Minnesota, and consequently any water-powers they can furnish are now of little value; however, as was stated in describing the main river, these will increase in importance as the state becomes older, the country more thickly settled, and manufactures are in greater demand. That water-

power exists upon these streams we know from the published accounts of explorations and surveys, and that in part at least it can be made available when the demand for it exists, can hardly be doubted. Although the general surface is only rolling or slightly undulating, yet many of these streams have rapids in their courses, just as the Pokegama falls and Grand rapids occur in the main river. The tributaries above the mouth of the Crow Wing river are comparatively small. The Leech Lake river, with its basin of 1,105 square miles, is the largest, and does not fall far short of the entire drainage area of the river above the junction. Succeeding the Leech Lake river in size, the most important tributaries are the Pine, 961 square miles; the Willow, 509 square miles; the Prairie, 491 square miles; the Sandy Lake, 421 square miles; the Swan, 349 square miles; and the Turtle, 300 square miles. Following these are the Rice, the Pinniddiwin, the East branch of the Mississippi, and several others of smaller extent of drainage. These tributaries will vary from 450 theoretical horse-power under a head of 10 feet at their mouths, with the ordinary low flow, down to an inconsiderable amount. They include within their limits probably the most extensive system of natural reservoirs to be found in the entire Mississippi basin, and this fact should add very much to their value as water-power streams. The Leech Lake river is the most conspicuous example. Leech lake, of which it is the outlet, has an area of 176 square miles, and is a great reservoir, equalizing the flow, in which it is aided by numerous smaller bodies of water. The descent of Leech Lake river is slight, as the total fall is only 13.6 feet in about 18 miles. Nevertheless it is probable that an available power exists upon the stream, as the recommendations of the government engineers include a dam and reservoir upon it. With the large storage capacity available, a water-power upon Leech Lake river would be very steady. With the ordinary low flow a head of 10 feet would afford at least 460 theoretical horse-power.

Pine river would afford at its mouth, under a head of 10 feet and with the ordinary low flow, about 325 theoretical horse-power. The headwaters are at the divide, limiting the feeders of Leech lake, and hence the total fall of the river cannot be less than 120 feet. There are rapids in the river, and points at which it is proposed to construct dams for the purpose of making storage reservoirs. Prairie river has rapids in its course where it crosses the same ridge of rock which causes the Pokegama falls. The east branch of the Mississippi is also described by Schoolcraft as having some very strong rapids in its upper portion, as indeed must be the case, for it heads near Itasca lake, and flows in the same general direction as the Itasca branch, which is very rapid in its descent for a large part of its course.

CROW WING RIVER.

This stream, with its drainage area of 3,560 square miles, is the largest tributary of the Mississippi above the Minnesota river. Starting almost at the utmost spring of the Mississippi, it flows 105 miles, in a general southeast direction, and enters the Mississippi about 390 miles below its source. There are a number of lakes within the basin which anywhere else but in Minnesota would be one of its marked characteristics, but there are so many more in the basin of the Red river of the North adjoining on the west, and in the region northward, as to make the Crow Wing basin appear rather scantily supplied in comparison. The principal lake is Gull lake, some 3 by 10 miles in extent. The chief tributaries, from the source down, are the Shell, the Red Eye, the Partridge, the Long Prairie, and the Gull, of which all but the first enter the lower third of the river. On this account over half the basin drains into the lower third of the river only. The section of country tributary to the Crow Wing is very largely a wild, uncultivated region. Lumbering has been the chief business for some 20 years, and as a consequence all the pine has been cut away except about the upper tributaries, where the logging is now done. The southern portion of the basin, drained chiefly by the Long Prairie river, extends somewhat into the settled region of the state, and consequently we find there what is probably the farthest north of all the flouring- or grist-mills of the upper Mississippi basin. It is situated on the Long Prairie river, and uses 54 horse-power under a head of 7 feet. There are two, possibly three, saw-mills in the basin of the Crow Wing, using about 50 horse-power under a head of from 7 to 10 feet, and these, with the grist-mill, embrace all the water-power utilized. No power is taken from the Crow Wing itself. The total fall from the source to the mouth cannot be far from 500 feet, and rapids occur in the stream. Probably there are localities where the power will be utilized in the future. The power at the mouth, with the ordinary low flow, under a head of 10 feet, is about 1,200 horse-power. The Northern Pacific railroad crosses the river at Motley, about 15 miles from the mouth, and for some 10 miles of this distance runs near the stream.

The Long Prairie river enters at Motley from the south. The scheme has been proposed of running a railroad from the Northern Pacific at Motley, southwest through Minnesota, striking the Minnesota river at Lac qui Parle, and then passing into southern Dakota. By this there would be a more direct route for the passage of lumber and grain. It would make Motley an important point, and might lead to the development of a water-power, which from a passing view it would seem possible to improve at that point.

TRIBUTARIES BETWEEN THE CROW WING AND THE MINNESOTA.

For the distance of 136 miles the chief branches of the main stream are the Crow, the Rum, the Sauk, and the Elk rivers, but there are a number of smaller tributaries, each draining from 100 to 300 square miles. Below the Crow Wing river the Mississippi enters a region of country more fully settled, where there is more demand for

water-power, and consequently there are several small custom flouring- and grist-mills and saw-mills, which are run by these smaller tributaries of the Mississippi. Among them may be mentioned the Platte, Watab, Two Rivers, Little Elk, and Clearwater rivers. There are altogether about twenty industries taking their power from the small branches of the Mississippi, which power varies in amount from 15 to 75 horse-power, under a head ranging from 4 to 19 feet. All are flouring- and grist-mills or saw-mills, with the exception of one door and sash factory on the Clearwater river.

SAUK RIVER.

This river has a general southeast course and enters the Mississippi from the west just at the head of Sauk rapids. Near the mouth it is 150 or 200 feet wide. The drainage area is 968 square miles, and includes only a few lakes. The soil through which the river flows is sandy or clayey in nature. The power at the mouth under a head of 10 feet and with the ordinary low flow is estimated in the tables to be 329 theoretical horse-power. The proprietor of a mill at that place stated that about 300 horse-power was obtainable under a head of 8 feet. The shape of the basin is such as to make the river maintain its size for a considerable distance from its mouth.

There are seven industries obtaining power from the Sauk river, all of them flouring- and grist-mills. The highest head used is 18 feet and the smallest is 6 feet. The largest power is 150 horse-power under a head of 12 feet, and the smallest is 12 horse-power under a head of 6 feet. The total power in use is 505 (effective) horse-power.

ELK RIVER.

The Elk river has the peculiarity of rising only 15 miles from the Mississippi and entering it after flowing about 100 miles in a nearly parallel course along the east side. The drainage area is 587 square miles in extent, and a very large part of it is tributary to the Saint Francis, a branch of the Elk river, which enters it from the east about 10 miles above the junction with the Mississippi. The name Saint Francis, according to Schoolcraft, was formerly given to the entire river. At this junction is the town of Elk River, the county seat of Sherburne county. The railroad crosses the Elk river 3 or 4 miles above the mouth, and there the river is some 100 or 150 feet wide, with steep banks of earth about 10 feet high. The estimated power in the tables for the ordinary low flow at the mouth under a head of 10 feet is about 180 theoretical horse-power; above the Saint Francis it is probably not over one-half this amount. The only power used from the Elk river is at a point about 1.5 mile from the mouth, where there are three establishments working under a head of 9 feet. They are rated as follows: A flouring-mill using 200 horse-power, a saw-mill using 100 horse-power, and a furniture factory using 20 horse-power. Of course all three cannot work at full capacity in a low stage of the river. There are other powers which it is possible to develop, of which one is situated near the railroad bridge. There is one establishment upon the Saint Francis river, a saw-mill using 30 horse-power under a head of 9 feet of water.

CROW RIVER.

Five miles below the mouth of the Elk river this stream enters from the west. With its drainage basin of 3,085 square miles it is the largest tributary, with the exception of the Crow Wing, which flows into the Mississippi above the Minnesota river. The basin of the Crow consists chiefly of rolling prairie, interspersed with groves of hard-wood timber and is largely cultivated. There are a number of lakes within its limits, some of them 4 or 5 square miles in extent. About 18 miles from its mouth the Crow river separates into the North fork and South fork, which are by map measurement 96 and 80 miles long, respectively. The area of the basin is nearly equally divided between the two, but the North fork is considered the larger. This impression is very probably due to its draining more lakes than the South fork, and, as it is steadier in its flow, appearing larger in low water. The South fork has a tributary called Buffalo creek, which is 40 or 50 miles long. The Saint Paul, Minneapolis, and Manitoba railroad crosses the South fork at Delano, 3 miles above the junction with the North fork; the stream is there 75 or 100 feet wide at a low stage, with vertical rim-banks of clay, from 5 to 15 feet in height. Below the junction the Crow river averages about 350 feet in width. In the table the Crow river is estimated to give at the mouth, with the ordinary low flow, under a head of 10 feet, 1,050 theoretical horse-power. The greater part of this is supplied by the North fork, but how much it is impossible to say without gaugings. There is only one industry using the power of the South fork, a flouring- and grist-mill at Watertown, about 10 miles from the junction, using some 30 horse-power under a head of 8 feet. The proprietor is obliged to use steam part of the time. There was at one time a mill at Delano, but the dam was carried away and never rebuilt. This dam was made by driving piles into the bed and filling in with brush and stone. The banks at that place are 5 or 6 feet high. On the North fork and the river below the junction there is considerable development of power. Altogether nearly 1,000 effective horse-power is in use under heads varying from 6 to 14 feet. There are 11 flouring- and grist-mills using an aggregate of 655 horse-power. The remainder of the power is nearly all taken by saw-mills.

Power is used on the main river below the junction at four localities. There is a flouring-mill at the mouth; another just below Saint Michael's; a grist-mill and saw-mill at Hanover, and at Rockford are a flouring-mill, saw-mill, woolen-mill, and a cabinet-shop. This is the most completely developed power upon the river, but it is by no means

fully improved. Mr. Florida, the proprietor of the flouring-mill, states that "there is a sheet of water continually running over the dam, say from 4 to 5 inches deep." The head is 8 feet. The flouring-mill uses 95 horse-power, the saw-mill 60, the woolen-mill 45, and the cabinet-shop, 35, making a total of 235 horse power.

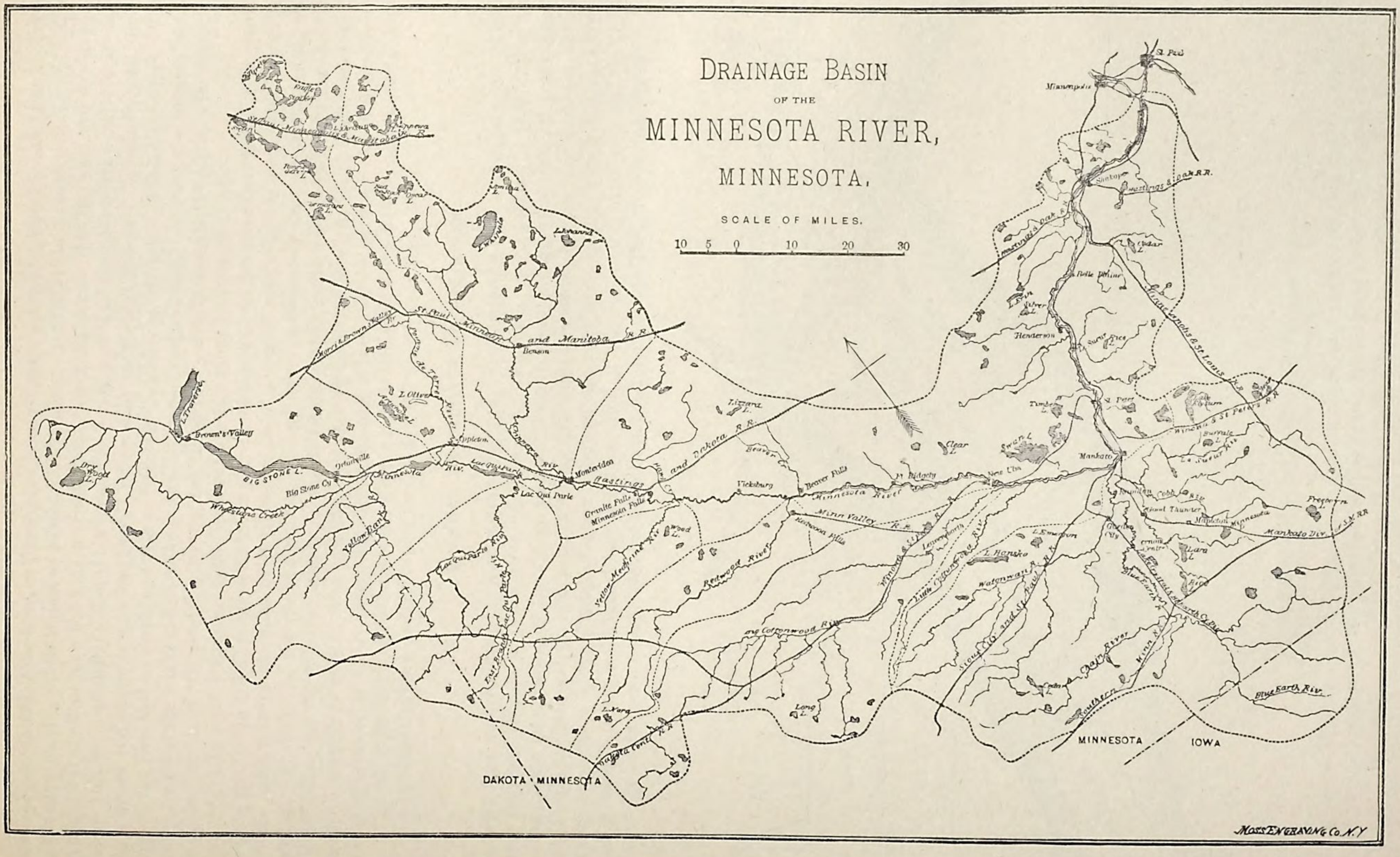
RUM RIVER.

The Rum river has a peculiar drainage basin. Like that of some streams in the state of Iowa it is long and narrow; about 80 miles long and not averaging over 19 miles wide, with a general north-and-south direction. The upper end is Mille Lacs, called by the Indians Michi Sagaigon, meaning "great lakes". It is 186 square miles in extent and the largest sheet of water in the basin of the upper Mississippi. As has been previously pointed out, its drainage area is almost limited to its own surface, as the line of water-shed is in no place more than 6 miles away from the shore of the lake. The Rum river, so named on account of color derived from the swamps and woods, starts from the southwestern part of the lake, and after flowing about 136 miles in a general southerly direction, enters the east side of the Mississippi at Anoka, 7.5 miles below the mouth of the Crow river. The Rum river has been extensively used for lumbering, and from 60,000,000 to 70,000,000 feet of pine are sent down every year, of which the most is sawed before it leaves the river, by mills worked either by water-power or by steam. There are many dams upon the side streams, used for the purpose of holding and flushing logs into the main river. The large body of water at the head of the drainage-basin serves an important part in maintaining the flow of the river during low water. The ordinary low-water discharge into the Mississippi is estimated to be 462 cubic feet per second, giving, under a head of 10 feet, 524 theoretical horse-power. Millers estimate that under this head from 450 to 550 horse-power is practically available. Owing to the large reservoir at the source, the river must maintain its volume in low stages well up toward the head. It is claimed by those familiar with the region that a few miles below the outlet of Mille Lacs a dam could be built with a fall of 6 or 8 feet, which would raise the level of the lake 1 or 2 feet without flooding any valuable land. By properly regulating the flow past this dam a very uniform stage of the river might be maintained. It must, however, be remembered that the drainage area tributary to the lake, outside of its surface, is limited, and that evaporation equals or exceeds 50 per cent. of the rainfall on a water surface in that climate. The owners of water-powers are of course desirous that Mille Lacs should be included in the reservoir system, but the government engineers exclude it on account of its limited drainage area. The Rum river is about 200 feet wide near the mouth, and when visited in the extremely cold winter of 1880–'81 at Anoka, had a strong current about 2 feet deep. The river flows chiefly between clay or sand banks, with usually a bowlder bed at the rapids, but where it crosses the ridge of granite which produces Sauk rapids on the Mississippi, there is a slight fall over rock in place. At only two localities is the power of the Rum river used. The first is at Anoka, some 2,000 feet above the mouth, where there are a flouring-mill and a planing-mill run by it. The head is 8 or 9 feet. The dam, early in 1881, was of brush construction, and leaked very badly. It backs the water about 3 miles up-stream. The other development is at Saint Francis, about 16 miles from the mouth, where a flouring- and a saw-mill use the power under a head of 9 or 10 feet. According to the census returns there is a total of 370 horse-power used from the Rum river, and there is one flouring- and grist-mill upon a tributary called the West Branch, using 50 horse-power under a head of 9 feet.

There are a number of available unutilized powers on the Rum river. It was stated by one familiar with the stream, that from the outlet of Mille Lacs down to Princeton, a distance of from 55 to 65 miles, there are several rapids and available water-power sites, while the banks are high enough to confine the water to the river channel. From Princeton to Saint Francis, a distance of 50 or 55 miles, the river is less rapid, and although there is some fall, yet the banks are low, and it is not so practicable to utilize the power. From Saint Francis down to the level of the Anoka power the river is quite rapid, and there are several available sites. At Oak Grove, about 12 miles above Anoka, is a rapid where the banks are high, and a pile dam could easily be constructed, giving 15 feet head of water. With the ordinary low flow this would afford nearly 800 theoretical horse-power.

MINNESOTA RIVER.

From this river, so called by the Dakotas, the state of Minnesota has received its name. The river was at one time called the Saint Peter's, from a Frenchman who settled at its mouth, and by this title it is described in the reports of early explorations, but a legislative enactment subsequently restored the old Indian name. It is, eminently, *the* river of Minnesota. Starting in Dakota, about 25 miles west of the boundary, the river flows 256 miles southeast and then northeast clear across the southern portion of the state of Minnesota, to join the Mississippi just below the falls of Saint Anthony, between the cities of Minneapolis and Saint Paul. With its drainage area of slightly more than 16,000 square miles, it is only exceeded about 3,600 square miles by the entire basin of the Mississippi above the junction. Although draining such a large extent of country, the Minnesota does not wield a proportionate influence with the other tributaries of the Mississippi. The country from which it runs is not well adapted to maintaining the flow of a large river through the dry season, and hence the Minnesota partakes largely of the characteristics of a prairie stream, a fact pointed out on a previous page.

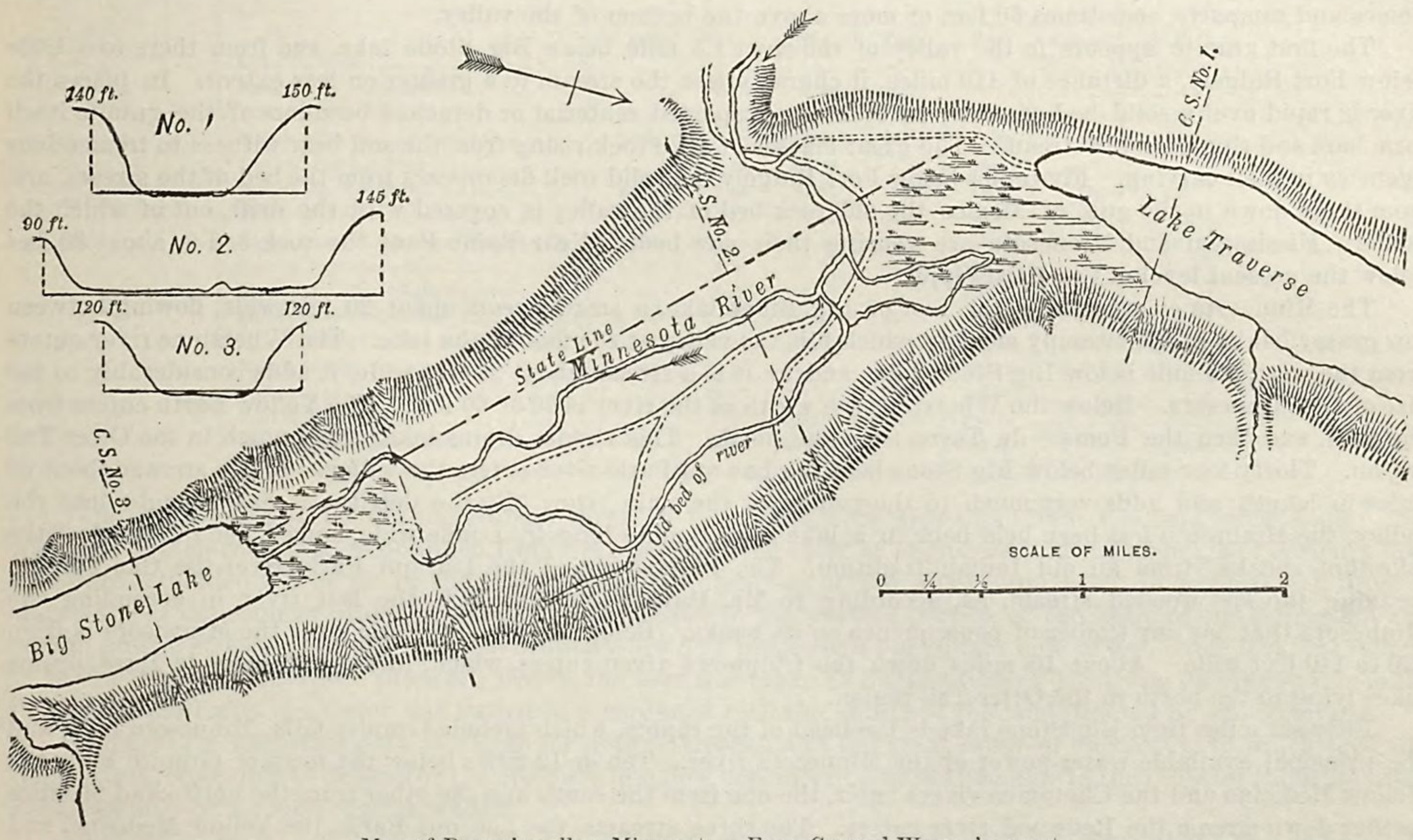

DRAINAGE BASIN
OF THE
MINNESOTA RIVER,
MINNESOTA.
SCALE OF MILES.
10 5 0 10 20 30
St. Paul
Minneapolis
Hastings & Dakota R.R.
Minneapolis & St. Louis
Minn. & St. Louis R.R.
St. Paul Minneapolis and Manitoba R.R.
Benson
Morris & Brown's Valley
Brown's Valley
L. Traverse
Big Stone L.
Big Stone Cy
Ortonville
Whetstone Creek
Yellow Bank
Minnesota Riv.
Lac qui Parle
Montevideo
Appleton
L. Olivet
Hastings
Granite Falls
Minnesota Falls
Vicksburg
Beaver Falls
Minnesota River
Minn. Valley R.R.
Redwood River
Yellow Medicine Riv.
Cottonwood Riv.
Watonwan R.
Blue Earth Riv.
Le Sueur Riv.
Minnesota & St. Louis R.R.
Mankato
New Ulm
Henderson
Belle Plaine
Shakopee
Cedar L.
Tamarack L.
Clear L.
Swan L.
L. Hanska
L. Emerson
Long L.
L. Varg
Dry Wood L.
Wood L.
Lizzard L.
Mankato Div.
Dakota Central R.R.
DAKOTA
MINNESOTA
MINNESOTA
IOWA
Moss Engraving Co. N.Y.

General description of the basin.—The drainage basin may be likened, roughly speaking, to a rectangle running southeast through the prairie region of southern Minnesota. On the north a projection forces the line of water-shed far up toward Otter Tail lake, the source of the Red river of the North. On the west and southwest the water-shed runs along the ridge of drift, called the Côteau des Prairies, which extends northwest into Dakota. A southern prolongation of the basin carries the line of water-shed for a short distance into Iowa, and limits the northern drainage of the Des Moines river, and thence the crest-line runs nearly north to the Mississippi. The area included within the limits of the basin embraces very fertile prairie land, and has been, with the country to the eastward, the wheat-raising region of Minnesota, until the Red River valley rose to dispute the claim. The eastern portion of the basin is very fully settled and the region westward is fast coming under cultivation.

On the prairie no trees are seen, and it is only on descending to the river-bottoms that they are found. There cottonwood and several varieties of hard wood, as oak, maple, elm, etc., are met with, but cottonwood is the characteristic growth. In the eastern portion of the basin the timber is more common, and a peculiar growth of hard wood called the Big Woods extends in a belt, 45 miles wide, northwest through the basin. The entire basin is either level prairie or rolling, with troughs cut below the general level, in which the rivers run. The bluffs on either side of these river valleys are generally steep, and it is on them or on the river bottom below that the timber grows. The Chicago and Northwestern, the Chicago, Milwaukee and Saint Paul, and the Saint Paul, Minneapolis and Manitoba railroads have various branches through the basin, from east to west.

GENERAL DESCRIPTION OF THE RIVER.

Starting from the treeless prairie of eastern Dakota, the Minnesota runs southeast some 25 or 30 miles to the boundary between Dakota and the state of Minnesota. Forming the boundary in that region are two peculiar lakes—Big Stone lake, called by the Sioux "Inyan Tonka", from the great masses of granite near by, draining southward into the Mississippi, and lake Traverse, draining northward, by the Bois de Sioux, into Hudson's bay. The first of these lakes is 26 miles and the last 23 miles long; each averages 1 mile or 2 miles in width. The general direction of lake Traverse is northeast and southwest, and of Big Stone lake, northwest and southeast. These two lakes lie really in the same valley, a fact alluded to in the report on the Red river of the North.



Map of Brown's valley, Minnesota. From General Warren's report.

The summit.—The lakes are between 4 and 5 miles apart, and the intervening tract, called Brown's valley, is the dividing ridge separating the waters of Hudson's bay from the drainage of the gulf of Mexico. It is hardly correct to call this the dividing ridge, for in times of flood there is water communication between the lakes. In the report of the chief of engineers for 1874 will be found detailed descriptions of this region, and of the entire Minnesota river, prepared under the direction of General G. K. Warren by Mr. C. E. Davis.

Brown's valley is about 1.5 mile wide, a rich alluvial region, 17 feet above lake Traverse and 22 feet above Big Stone lake. Through the bluff on the western side of this valley, about 1 mile below lake Traverse, the Minnesota has cut its gorge. It runs across the valley to its center, a stream from 15 to 30 feet wide, with banks 10 or 12 feet high, then turns and follows the direction of the valley down to Big Stone lake. A slough, 4 feet deep, 20 feet wide, and 6 feet above the bed of the Minnesota, connects with the swamps at the head of lake Traverse, and when the Minnesota is high there is a water-way, 1.5 foot or 2 feet deep, to lake Traverse.

It has happened that an ice-gorge upon the Red river of the North has backed the water up the valley over the crest, so that it has flowed down into Big Stone lake. The channel between the two lakes is easily navigated in high water by canoes. In 1862 or 1863 the attempt was made to float a small steamboat up the Minnesota river and over into the Red river of the North, but the boat was abandoned about 9 miles below Big Stone lake, where a few years ago the timbers were still to be seen.

The character of the summit between the two systems of drainage suggested the opening of navigation up the Minnesota, and so over into the Red River valley, and it was for this purpose that the survey just mentioned was made in 1868. Nothing has been done in connection with this improvement, which contemplated the construction of canals, dams, and locks along the Minnesota to the Mississippi river.

The bluffs which border Big Stone lake are from 130 to 150 feet high, abrupt, and rising to the prairie level on each side. Below the lake they continue at about the same height and distance apart, forming, with the bottom-land between them, the valley of the Minnesota. This valley continues clear to the Mississippi river, varying from 1 mile to 2 or 3 miles wide, and down it, winding from side to side, runs the Minnesota. At the foot of Big Stone lake the valley is from 1 to 1.5 mile wide; at the mouth of the Minnesota it is less than a mile wide.

Lake Traverse is thought by General G. K. Warren to have been formed by the river filling up the trough at Brown's valley and throwing back the water, while Big Stone lake is due to a similar action by the Whetsone river, which enters the Minnesota below the foot of the lake. When the drainage was limited to the immediate locality the river could not fill its old channel, and hence its crippled energies have been limited in their action to the sorting over of the ancient bed of the valley. Considerable changes have been wrought in this way, and by the side streams, which have worn deep gulches out of the bluffs on either side, spreading the *débris* upon the floor of the valley. The opportunities for the river to sink its new channel very far below the ancient bed are much restricted by the solid granite, which is only thinly covered with drift in places, or else rises in vast water-worn domes and ramparts, sometimes 50 feet or more above the bottom of the valley.

The first granite appears in the valley of the river 1.5 mile below Big Stone lake, and from there to a little below Fort Ridgely, a distance of 110 miles, it characterizes the stream to a greater or less extent. In places the river is rapid over a solid bed of rock; in others, transported material or detached bowlders of the granite itself form bars and ripples in the stream. The great masses of solid rock rising from the soil bear witness to tremendous agencies in their carving. Five miles below Fort Ridgely the solid rock disappears from the bed of the stream, and from there down to the gulf of Mexico the old rock-bed of the valley is covered with the drift, out of which the modern Mississippi and Minnesota are wearing their new beds. Near Saint Paul the rock-bed is about 80 feet below the present level of the Mississippi.

The Minnesota emerges from the foot of Big Stone lake, a small stream about 20 feet wide, flowing between low grassy banks in the swampy meadow which fills the valley at the foot of the lake. The Whetstone river enters from the west, 1.5 mile below Big Stone lake, and as it is a stream about 25 feet wide, it adds considerably to the size of the Minnesota. Below the Whetstone the width of the river is 50 or 60 feet. The Yellow Earth enters from the west, and then the Pomme de Terre from the north. This stream drains lakes away north in the Otter Tail region. Thirty-four miles below Big Stone lake the Lac qui Parle river enters the valley. It is a stream about 60 miles in length, and adds very much to the volume of the main river. By the detritus it has brought into the valley, the Minnesota has been held back in a lake some 6 miles long by 1 mile wide, named Lac qui Parle, "the lake that speaks," from an old Indian tradition. The Indians called the Lac qui Parle river the Cha-Tutpah, meaning the last wooded stream, as, according to Mr. Davis' statement, it is the last river in ascending the Minnesota that has any timber of consequence on its banks. Below the Lac qui Parle river the Minnesota is from 120 to 140 feet wide. About 10 miles down the Chippewa river enters, which, like the Pomme de Terre, drains lakes lying to the north in the Otter Tail region.

Fifty-six miles from Big Stone lake is the head of the rapids, which include Granite falls, Minnesota falls, and the principal available water-power of the Minnesota river. Ten or 12 miles below the town of Granite Falls the Yellow Medicine and the Chetomba rivers enter, the one from the south and the other from the north, and 21 miles farther down stream the Redwood river enters. The three streams, the Lac qui Parle, the Yellow Medicine, and the Redwood, drain nearly all the portion of the basin west of the river in Minnesota. On the north side of the river, after passing the Pomme de Terre and Chippewa rivers, the line of water-shed approaches the stream, and, hence, below that, all tributaries from that direction are small in size. On the south side, however, the water-shed runs about parallel with the river and 40 or 50 miles away, giving drainage sufficient to form streams like the Redwood. These streams greatly increase the size of the river, so that its bed is from 150 to 180 feet wide. Forty

miles below the Redwood is the mouth of the Big Cottonwood, and from 3 to 5 miles below is the Little Cottonwood. The Big Cottonwood is a large stream, 120 feet wide at the mouth, draining over 900 square miles of surface. The width of the Minnesota below the Big Cottonwood averages about 250 feet. Twenty miles below the Big Cottonwood is the great bend of the Minnesota, where it turns through more than 90°, and runs northeast to the Mississippi. At the angle the Blue Earth river enters from the south; it is by far the largest tributary of the Minnesota, draining over 3,000 square miles. With its tributaries radiating on each side, like the arms of a fan, it occupies the entire northern extension of the Minnesota basin, and rises in the prairie of northern Iowa. Below the Blue Earth the Minnesota basin contracts, and nothing but small streams enter the river. The width down to the mouth averages from 280 to 300 feet.

Slope of the river.—The slope of the Minnesota averages 0.89 foot per mile, and in only a few localities does it exceed or even equal 3 feet per mile. For the last 35 miles of the channel the slope is only 0.1 foot per mile. The practically available water-power is located upon the upper portion of the river, and, although it would be possible to develop water-power even where the slope is small, yet the expense attending such an improvement would practically prevent it on the river from the mouth up to near the Redwood river, a distance of about 170 miles. From there up to Big Stone lake are several available sites, which will be mentioned farther on. The river has been declared navigable up to Minnesota falls, a distance of 200 miles, and before the railroad ran up the valley boats used to ply up and down the stream to the Redwood river, and even beyond when the stage of the water would allow, but this was very uncertain and at times sudden in its fluctuations. Being a navigable stream it has been required that all bridges should be constructed with draws over the channel, and, accordingly, expensive structures are built, to be practically unused. There was talk when the river was visited, in the winter of 1880–'81, of endeavoring to have the portion of the river above the Redwood at least declared unnavigable. This would remove all legal restrictions to the construction of dams for purposes of water-power.

Table of data for the Minnesota river.

Station.	Area tributary above station.	Distance from preceding station.	Total distance.	Fall from preceding station.	Total fall.	Ordinary low flow per second.	Theoretical horse-power under a head of 10 feet.
	Sq. miles.	*Miles.*	*Miles.*	*Feet.*	*Feet.*	*Cubic feet.*	*H. P.*
Lake Traverse	.....	.....	.....	.....	.....	.....	.....
Head of Big Stone lake	.....	4.75	4.75	7.71	7.71	.....	.....
Foot of Big Stone lake	500	25.75	30.50	0.00	7.71	50	57
Mouth of Pomme de Terre river	2,999	20.13	50.63	30.12	37.83	180	204
Head of Lac qui Parle	.....	6.19	56.82	8.64	46.47	.....	.....
Foot of Lac qui Parle	4,086	7.46	64.28	0.00	46.47	355	403
Mouth of Chippewa river	6,030	12.25	76.53	14.20	60.67	550	624
Head of rapids, including Granite falls	6,180	10.00	86.53	6.92	67.59	560	635
Foot of Minnesota falls	6,185	5.38	91.91	49.78	117.37	560	635
Mouth of Yellow Medicine river	7,434	4.65	96.56	8.02	125.39	685	777
Mouth of Redwood river	8,422	21.15	117.71	43.45	168.84	785	890
Mouth of Big Cottonwood river	10,447	39.83	157.54	35.75	204.59	900	1,021
Mouth of Blue Earth river	14,519	19.57	177.11	27.02	231.61	2,050	2,325
Belle Plaine	.....	39.93	217.04	57.30	288.91	.....	.....
Foot of Little rapids	.....	9.11	226.15	7.28	296.19	.....	.....
Mouth of Minnesota river	16,027	35.50	261.65	0.40	296.59	2,500	2,836

Flow of the river.—The drainage areas given in this table were measured from the land-office maps; the distances and elevations were obtained from the reports of the chief of engineers, and the amounts of ordinary low flow were estimated by the aid of the tables deduced in treating of the Mississippi basin in general, and from a knowledge of the country drained. Some of the streams in the western portion of the basin of the Minnesota are typical prairie streams, and for them an ordinary low flow per second per square mile of 0.06 cubic foot was taken. In the eastern portion, where there are woods, the flow was taken as high as 0.25 to 0.30 cubic foot per square mile. Between these limits the factor was varied in accordance with the nature of the land drained by the tributaries.

Owing to the uncertain data available for prairie streams, and the great range of fluctuation to which they are subject, it is impossible to determine the ordinary low flow accurately, and the amounts in the table for the Minnesota are given only as a rough approximation.

The lines of equal precipitation on the rainfall chart run nearly parallel with the river above the great bend, and hence, while the tributaries from the north have only about 25 inches of annual precipitation upon their basins, those from the south have from 26 to 30 inches. That this difference exerts any great effect upon the ordinary low flow is not certain. It must be understood that the figures for flow will not apply to the river for severe winter weather, when it dwindles down to a discharge of even 800 cubic feet per second at the mouth, and some of the prairie tributaries are frozen solid at their headwaters. Neither are they applicable to very dry seasons in summer and fall.

The Minnesota probably discharges in high floods 60,000 cubic feet of water per second, when the melting snow and heavy rains on the prairies are pouring rapidly into the valley. The following gaugings at the mouth in 1867 are taken from tables in the chief of engineers' reports:

Date.	Cubic feet per second.	Date.	Cubic feet per second.
June 22	22,819	October 8	2,482
July 6	27,034	October 10	1,696
July 10	22,040	October 17	1,983
July 13	17,272	October 21	1,277
July 17	11,784	October 25	1,824
July 31	17,087	October 30	1,290
August 14	11,410	November 2	1,316
September 4	4,521	November 6	1,826
September 19	2,881	November 14	1,271
September 20	3,797	November 23	1,582
October 2	2,025	November 27	1,342

General G. K. Warren states:

By the time the snow is melted in the upper valley the spring rains set in and last until the latter part of June, when the river is usually at a high-flood stage. From that time it falls rapidly. * * * Sometimes heavy rains occur in August and September, which give several feet rise; but the rains are of short duration, and the river falls so quickly that steamboats do not go up the river on account of the risk of its falling before they return. * * * The river is usually closed by ice from November 20 to April 15, and sometimes much longer. * * * The periodical rains cause a rise from low to high water of 26 feet.

The statement was made by one of the manufacturers at Granite falls that a 10-foot rise at that place was a very high one.

It will be seen from the figures given relative to the flow of the river, and from the description of the country drained, that the Minnesota and most of its tributaries are low-flow streams, depending very largely for maintenance of flow through the year upon a uniform distribution of the rainfall. This they do not get, and hence, unlike the wooded and swampy tributaries at the headwaters of the Mississippi, most of the upper branches of the Minnesota run very low in the dry season, or when severe cold freezes the prairie surface solid may even cease running entirely at their sources. These conditions produce their due effect upon the main stream, and the unsteady character of the flow from so large a portion of the basin of the Minnesota river is detrimental to its water-power.

WATER-POWER SITES ON THE MINNESOTA RIVER.

There are only three establishments using power from the river. They are situated at or near Granite falls, and will be described in course. It is proposed now to give a description, so far as possible from the information obtained, of the location and character of the available water-power sites along the river from Big Stone lake down.

The outlet of Big Stone lake.—The flow of water from Big Stone lake is too small to afford any large power, but it would be possible to run a fair-sized custom mill by the river at that place. The valley is about 1 mile wide between the steep bluffs—a rich alluvial plain of dark sandy loam. At the shore of the lake the banks are swampy and scarcely elevated above the water.

The state line between Minnesota and Dakota passes lengthwise along the valley, and is marked by an iron monument near the lake. Upon the Minnesota bluff is the village of Ortonville, and opposite, on the Dakota bluff, the village of Big Stone City. A wagon-road crosses the valley between the two places, and at Ortonville is the landing for a steamboat which navigates the lake. The Hastings and Dakota division of the Chicago, Milwaukee, and Saint Paul railroad crosses the valley into Dakota a little below the lake, but a side-track runs up to the steamboat landing. The depot is about one-quarter of a mile below the town.

The end of the lake is nearly square instead of pointed, as represented on most of the maps, and is said to be slowly creeping up the valley, being now several hundred feet above where it is represented upon the government plats. From about the center of this end shore of the lake, the Minnesota emerges between sedgy banks scarcely more than 1 foot high. Just below where the wagon-bridge crosses it, the width is about 20 feet, and on January 18, 1881, the water was about 1 foot deep, with an average velocity, roughly measured, of 1.2 foot per second. This would give a flow of 24 cubic feet per second.

The variation in the discharge of the lake is more dependent upon the direction of the wind than upon anything else; a freshet is not so much caused by rain or melting snow as by a strong wind from the northwest, which if it continue for several days will send waves down the lake 3 feet high or more, and raise the level so as to flood the flat. When the wind subsides, the flow of the river is very much diminished, until the lake is replenished. There is a demand for a flouring-mill in the vicinity, which will increase as this region, scarcely opened up before 1879, becomes more settled. There is already a steam mill proposed at Ortonville, which will probably be built, being preferable to an investment in the water-power, but with considerable expense such a power could be developed.

By building an embankment across the valley about 1 mile long and 4 feet high, the waves would not break over it to any considerable extent, and the discharge could be regulated more uniformly. A quarter of a mile down-stream the banks are about 9 feet high, and by building a short dam across the river, with wing-dams connecting with the dam across the valley, it would be possible to obtain a head of 8.5 feet with the lake-level raised about 1.5 foot. It was claimed by those familiar with the matter that five runs of stones could be worked with the greatest ease, and it would be possible to run nearly twice that number. By locating the mill one-half mile farther down, the head would be 9 feet, and one-half mile farther a head of about 10 feet could be obtained. The lake dam would have to be riprapped to protect it from the action of the waves.

The Whetstone river, which enters the Minnesota river 1.5 mile below Big Stone lake, drains a considerable area, and is a large stream in spring. By a dam it is said to be possible to turn it into the lake through an old channel, and it would assist very greatly to increase the body of water. It would be turned off from two farms if this plan were carried out.

Below Big Stone lake.—From the outlet of Big Stone lake down to near Granite falls the average slope of the river is only about 1 foot per mile, and any available powers, if they exist, must be utilized by throwing a dam across at an advantageous point and flooding up-stream for a considerable distance. So far as could be learned from inquiry there is no location in a good condition to be improved without considerable expense, but very likely there are sites that could be developed more readily than that at the foot of Big Stone lake. Just below the mouth of the Pomme de Terre river is a site where it was said that, with considerable expense, a head of 8 feet could be obtained.

Granite falls.—Before any water-power improvements were made upon the Minnesota there was a series of rapids extending for nearly 5.5 miles down the stream, and about at the center of this distance are Granite falls, from which the village near by takes its name. The total descent of these rapids is 49.78 feet, or 9.25 feet per mile. At the foot are Minnesota falls, which will receive notice farther on. The larger part of the descent is at Granite falls, where a fall of about 35 feet is concentrated within a distance of not over 1 mile.

The first improvement found upon these rapids in passing down-stream is at Hickson's mill, 2 miles above Granite falls. With a head of 7 or 8 feet the water is backed up the river about 5 miles. Mr. Hickson has there a small custom-mill, with three runs of stones. From this mill down to Granite falls there is no improvement of the water-power.

Granite Falls is the name given to a place in the river where the water falls about 9 feet over a granite rib, which extends across the stream. The river flows southeast above the falls, close along the left-hand bluffs of the valley, but there it turns and runs nearly south for about 2,000 feet, and then takes another bend to the southeast. This leaves a broad plain, level or slightly rolling, and on this is the village of Granite Falls, the county seat of Yellow Medicine county. Beyond the plain the true valley bluffs rise, and beyond these stretches the fertile prairie.

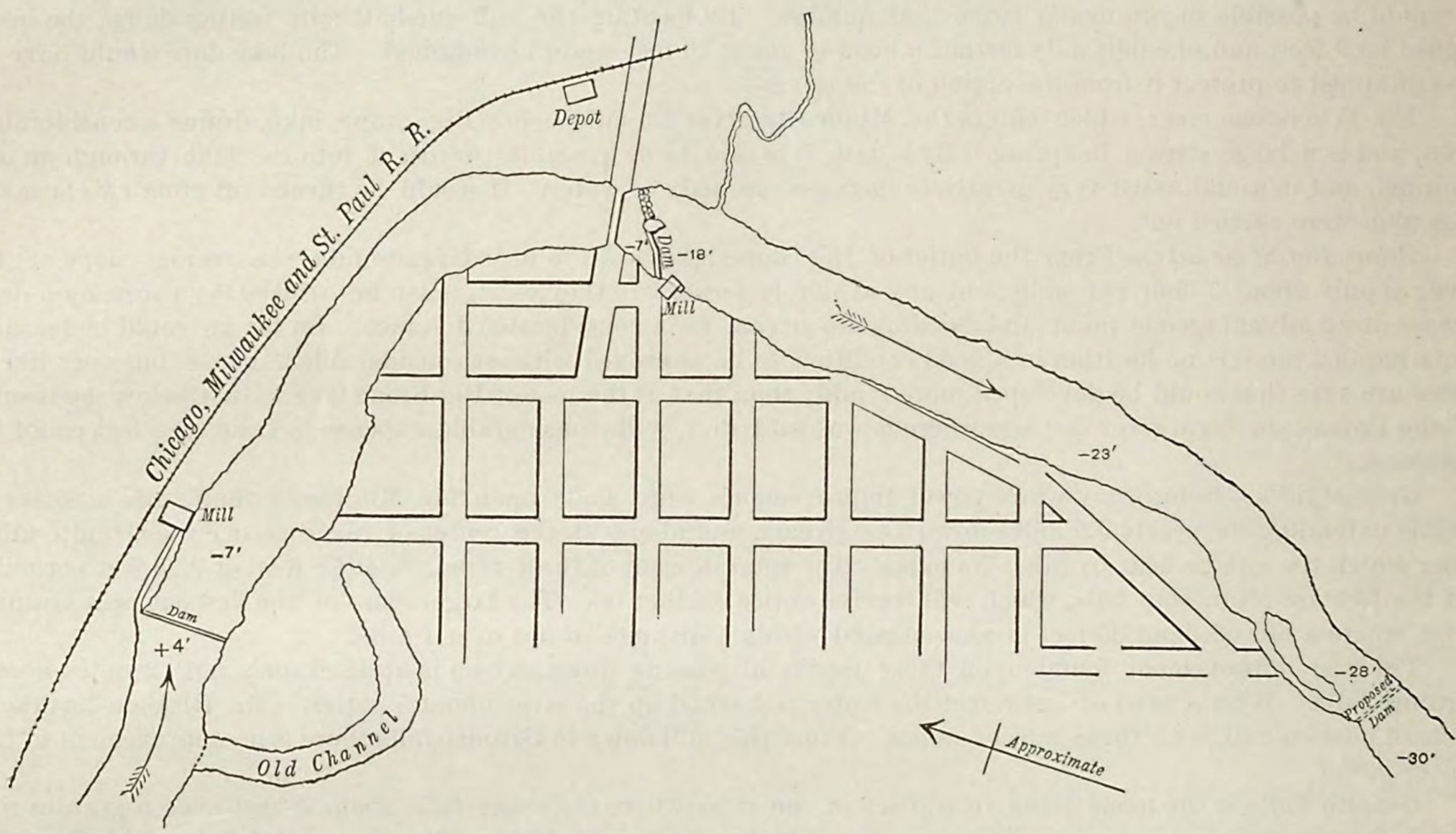
The railroad which runs up the Minnesota to Big Stone lake first enters the valley at Granite Falls, and the station is on the opposite side of the river from the village, to which a highway bridge crosses just above the falls. The granite in place crops out in the valley in large masses, especially west and southwest of the village, where are immense roughly-rounded ridges and knobs rising from the plain, almost deserving of the name of hills. The bluff on the left bank of the river continues in a southeast direction.

The upper bend in the river toward the south is apparently caused by a rocky ridge which runs in that direction. The left bank, which was steep and high, now lowers to a slope of perhaps 20 degrees, rising 15 feet above the water. The right bank below the falls is from 10 to 20 feet high, a steep clay bank leading to the flat.

At the lower bend, where the river turns again to the south, the granite ridge which skirts the western side of the flat and the ridge on the east side of the river meet, and there the river forces its way in a channel about 175 feet wide between solid granite walls from 10 to 20 feet or more in height, carved and rounded by the erosion of the river. The prolongation up-stream of the direction of the channel below the lower bend passes directly along the base of the granite ridge already mentioned, and in this direction are the unmistakable marks of an old river-channel carved through the rocks. This old channel extends up the plain 4 miles and then meets the river once more. In floods it is still used by the surplus waters of the river, and through it the steamboat passed which has been mentioned as attempting to cross over into the Red river of the North.

Mills at Granite Falls.—The only power used in the vicinity of Granite Falls is taken by two flouring mills. One is about half a mile above the falls. An old log and brush dam gives a head of 4 feet, and a race running along the left bank 600 feet increases the head to 11 feet. The mill is a small one of only three runs of stones. The race is about 10 feet wide; the pond backs up to within about 2 feet of the level of the tail-race of Hickson's mill. It is the intention of the proprietor to build a substantial masonry dam and erect a large merchant flouring-mill. It would be possible to increase the head nearly 2 feet, and as the right bank is very low at the dam, this would necessitate the building of a short embankment. The bed of the river at the dam is of clay and bowlders, and the banks are of clay. The other mill is situated directly at the falls, at a situation admirable for the construction of a dam. The granite rib which forms the falls extends part way out from the left bank, above the water-surface, and it was only necessary to build the dam across the remaining space on the solid rock bed.

By backing the water up to the tail-race of the mill above a head of 11 feet is obtained directly at the dam. It is utilized by a flouring-mill on the right bank, which takes 125 horse-power. During the severe winter of 1880–'81 this mill ran five runs of stones, by filling the pond during the night and gradually drawing it down during the day. This is the last mill on the Minnesota river.



Minnesota river at Granite Falls, Minnesota. (The levels are approximate.)

From the description given it will be seen that with the present dams all the fall is improved from the head of the rapids to the foot of the falls.

Below the falls the river is rapid to beyond the lower bend. A line of levels was run on the ice from the lower bend up to the tail-race of the mill, and the fall was estimated to be between 10 and 15 feet.

The power is owned partly by the Messrs. Pillsbury, who are so largely interested in the mills at Minneapolis. There is some legal difficulty in the way of its development, but this can be settled, and it has been proposed to build a dam at a point a few hundred feet above the lower bend. The left bank is low, and would probably be flooded to some extent.

It was proposed some time ago, before the present interests were established, to run a race from near Hickson's dam down the flat to near the foot of the old channel, and there make a basin, along which to station mills. By this means a head of at least 30 feet could be obtained.

The river is not so rapid from the lower bend down to Minnesota falls, 2 miles below Granite falls, but at one point, about half-way between, is an island, past which the descent is more concentrated, and there a dam could be constructed, but with the power at Minnesota falls and above fully improved there would not be sufficient fall left at this point to be of value.

Minnesota falls.—This is a concentration of the descent over granite rock at the foot of the 5.5 miles of rapid water. The village of Minnesota Falls is upon the right bank at this place, and it was the expectation that it would be the principal town of the region, but the construction of the railroad determined that for Granite Falls. There is a log and stone dam on solid granite at this point, and just below are the ruins of a flouring-mill, which was burnt shortly after its erection.

The head available at the mill-site with the present dam is about 10 feet. It is the intention of the proprietors to rebuild, and by means of raising the dam so as to flood out rapids above, also blasting out a tail-race in the rapids below the mill, a head of 16 or 17 feet can be obtained.

Below Minnesota falls.—As the river is declared a navigable stream below this place, riparian owners would have no right to improve any water-powers that might exist. There are several locations, however, which are otherwise available, and in course of time it may be that they will be developed.

The river is not so rapid below Minnesota falls as in the stretch of rapids above, yet in the distance of 21 miles from the Yellow Medicine, which enters 4.5 miles below, to the Redwood river, the average slope is 2.05 feet per

mile, and at least three places afford opportunities for obtaining water-power. These are Patterson's rapids, Sacred Heart island, and a point about 2 miles above the mouth of Redwood river. There is also a location 1 or 2 miles below the mouth of the Redwood river. So far as could be ascertained these are the only water-power sites from Minnesota falls down to the mouth of the river which offer any good opportunities for improvement; there may be others, but no knowledge could be gained concerning them. The exceedingly severe winter weather of January, 1881, prevented any detailed examination of the river.

Patterson's rapids are about 13 miles above the mouth of the Redwood, and Sacred Heart island is 3 miles below the rapids, and at both places a head of about 8 feet can be obtained. The bed and banks are solid granite. At Patterson's rapids the plan of development would probably be to use an old deserted channel about 1.5 mile long, part as a head-race and the lower portion for a tail-race, placing the mills between. The property is owned by the proprietors of the Minnesota Falls power. At Sacred Heart island the location is very fine for building a dam across each channel to the island.

The place 2 miles above the Redwood is described as affording a head of 16 feet by the building of a dam about 200 feet long. The bed and banks are solid rock. The site below the Redwood river would give a head of 16 feet. The dam would be built on a rock foundation, and the water carried in a race some distance down stream.

Probably both of these last two powers could not be developed without interfering with each other.

Three miles above New Ulm are rapids, and also below the town are some powers, but it is the opinion of those familiar with the river that the expense of improvement would outweigh all value of the power. Then from the height to which floods rise in the river there would necessarily be times when back-water would destroy the head. This disadvantage would be met, although perhaps in a limited degree, upon any developed water-power on the Minnesota river. The statement made at Granite Falls, that a 10-foot rise was an unusual one there, would probably scarcely apply to any other portion of the river's course, because there the steep descent permits the water to flow off rapidly.

TRIBUTARIES OF THE MINNESOTA.

The principal tributaries for power are the Blue Earth and its branches, the Redwood, the Big Cottonwood, the Chippewa, and the Pomme de Terre. The prairie streams are very uncertain, and little dependence can be placed upon them except during the wet months of the year. Then they run full; but, with no woods and very little swamp or lake area to hold the water, they afterward dwindle away to small size. When the cold of winter freezes the prairie, they may be nothing but a mass of solid ice at their headwaters, receiving the flow from a few living springs farther down.

Nevertheless, these streams are made use of to drive the machinery of flouring-mills of small size, sufficient to do the local grinding, and on some of the larger ones less subject to the prairie influences there are mills doing a considerable business.

These tributaries of the Minnesota have a rapid descent, and are not lacking in power so far as that factor is concerned. Many of them enter the Minnesota valley with a slope of 10 feet or more per mile. They have cut their ravines deep below the general level of the prairie, and come out upon the floor of the valley 100 or 200 feet below; hence, judging from this descent, the smaller streams at least must have many rapid places in their courses.

WHETSTONE RIVER.

Thus the Whetstone river, which enters from the west just below Big Stone lake, has a mill, the only one upon it, at which, by tunneling through a neck of land, a head of 32 feet is obtained, and by raising the dam it could be increased to 40 feet. This mill has two runs of stones, but about three could be operated most of the time. This river is very small in low water.

LAC QUI PARLE RIVER.

The Lac qui Parle is similar in this respect, almost drying up at times.

Small streams.—Before proceeding to the description of the more important tributaries, it should be stated that there are several small streams not mentioned at all which, unsteady though they may be, yet can be used in the future to furnish power for small mills. Notable among these is Beaver creek, which enters from the north 2 or 3 miles below the Redwood river. There are two mills upon it; one noted in the census returns as using 30-horse power under a head of 17 feet, also using steam; the other using 12-horse power under a head of 30 feet.

POMME DE TERRE RIVER.

This stream flows almost directly south. Rising very near Otter Tail lake, the source of the Red river of the North, it drains several lakes, chief among which are Turtle, Christina, and Pelican lakes. On account of this tribute which the lake region of Minnesota offers to the Minnesota basin, the Pomme de Terre is more steady in its flow than the true prairie tributaries, especially in summer. During cold winters the lakes are not always sufficient to prevent its falling away, but the mills rarely have to stop on that account. The Pomme de Terre is about 100 miles long, but as the basin is long and narrow, no tributaries of importance enter it. Its valley, as well

as that of the Chippewa, which flows parallel to it on the east, is from one-quarter to one-half a mile wide, with bluffs 75 or 100 feet high most of the way. These valleys are considered by Professor N. H. Winchell to have been probably lines of drainage from the retreating ice-fields of the north leading into the main Minnesota trough. Like the modern Minnesota, the Pomme de Terre and the Chippewa are almost lost in their large valleys.

The railroad crosses the river about 10 miles from the source, and thence down to the mouth the total fall is not far from 250 feet. From where the railroad crosses it about 30 miles above the mouth, there is a descent of 100 feet. The average slope of about 3 feet per mile affords available powers. The banks and bed of the river are sandy gravel and clay, and the banks are generally high enough to prevent flowage from dams.

There are five improved powers upon the Pomme de Terre. The first is at Appleton, on the railroad, 2.5 miles above the mouth of the river. A flouring-mill there uses four runs of stones under a head of 10 feet, and part of the year power could easily be obtained for six runs.

The dam, about 75 feet long, is built on the clay bed of the river, of logs, brush, and stone, planked over. Just below the mill is a bend in the river, with a steep eroded bluff, some 30 feet high. Over this the snow has been known to drift level with the top and flood the water back upon the mill. Two miles above is a mill using about 40-horse power under a head of 10 feet. There advantage has been taken of a bend in the river, a canal cut across the neck, and about half the flow carried through it. About 20 miles from the mouth is a mill with a head of 8 feet and rated at 24 horse-power. Above this is a mill rated in the census returns at 70 horse-power under a head of 10 feet; and still another above, in Otter Tail county, at 70 horse-power under a head of 18 feet.

There are some undeveloped water-power sites of which information could be secured, and undoubtedly many others exist. From Appleton down to its mouth the river is rapid, and in that distance of 2.5 miles at least one fine power can be obtained.

By building a short dam about a quarter of a mile below the railroad track and carrying the water in a race across a neck of land, a head of 17 feet can easily be used. This power is considered by the millers equivalent to eight runs of stones. Two sites were mentioned, about 6 and 12 miles, respectively, above Appleton, where a head of 8 or 10 feet is available; and then, again, near the town of Elbow Lake, on the upper portion of the stream, there are two sites, one of which would afford a head of 14 feet and the other 8 feet. A miller familiar with the stream considered that a head of 14 feet in that section would afford sufficient power for four runs of stones.

CHIPPEWA RIVER.

This stream rises near the region drained by the headwaters of the Pomme de Terre, and like it drains several lakes, the largest being lake Whipple, about 7 miles long by 1.5 mile wide.

The basin is rather larger than that of the Pomme de Terre, spreading out toward the east so as to afford a tributary some 35 miles long, called the East branch, which enters the main stream at Benton, about 30 miles from the mouth. The Chippewa is somewhat similar to the Pomme de Terre, but appears to be rather more unsteady in its flow, probably because it drains a larger area of prairie country, not supplied with lakes.

The nature of the valley and of the bed and banks is like that of the Pomme de Terre. According to the railroad levels, the total fall from about 10 miles below the source to the mouth is slightly more than 400 feet, giving an average slope of about 5 feet per mile. There are several unimproved powers.

According to the census returns there are five mills upon the main stream and three upon the East branch.

In the first 12 miles above the mouth of the river are two flouring-mills, one using 22 horse-power under a head of 8 feet, and the other 36 horse-power under a head of 7 feet.

Above the junction of the East branch are the remaining three mills, in the following order, up-stream: 33 horse-power under a head of 15 feet, 69 horse-power under a head of 21 feet, and 26 horse-power under a head of 15 feet; the latter is near the headwaters. The mills upon the East branch are situated at Swift falls and at Chippewa falls, above. At the former is a flouring-mill, using 35 horse-power under a head of 12 feet, and at the latter are a flouring-mill and a saw-mill, using, respectively, 30 and 23 horse-power under a head of 18 feet of water.

YELLOW MEDICINE RIVER.

This is the first tributary on the west or right bank of the Minnesota of any size below the Lac qui Parle river. It runs back 50 or 60 miles into the prairie, and drains about 600 square miles. Near its mouth the river is from 30 to 50 feet wide, with steep clay and gravel rim-banks rising from 10 to 20 feet. It is an unsteady stream, pouring a large volume of water into the Minnesota when in flood. About 5 miles back from the Minnesota valley is the only mill upon the stream, a flouring-mill of 2 or 3 runs, using a head of 20 feet of water. Below the mill the stream is more rapid than above, for it there has a swift descent through its gorge to the Minnesota valley. In the valley itself it has an average slope of nearly 5 feet per mile. There are some unimproved water-power sites.

REDWOOD RIVER.

The Redwood has the same general course as the Yellow Medicine, and drains pretty much the same character of country, but is somewhat larger. Its total length is about 70 miles. At the headwaters is lake Benton, given on the land-office maps as about 5 miles long and from 1 to 1.5 mile wide. This lake serves to some extent to regulate

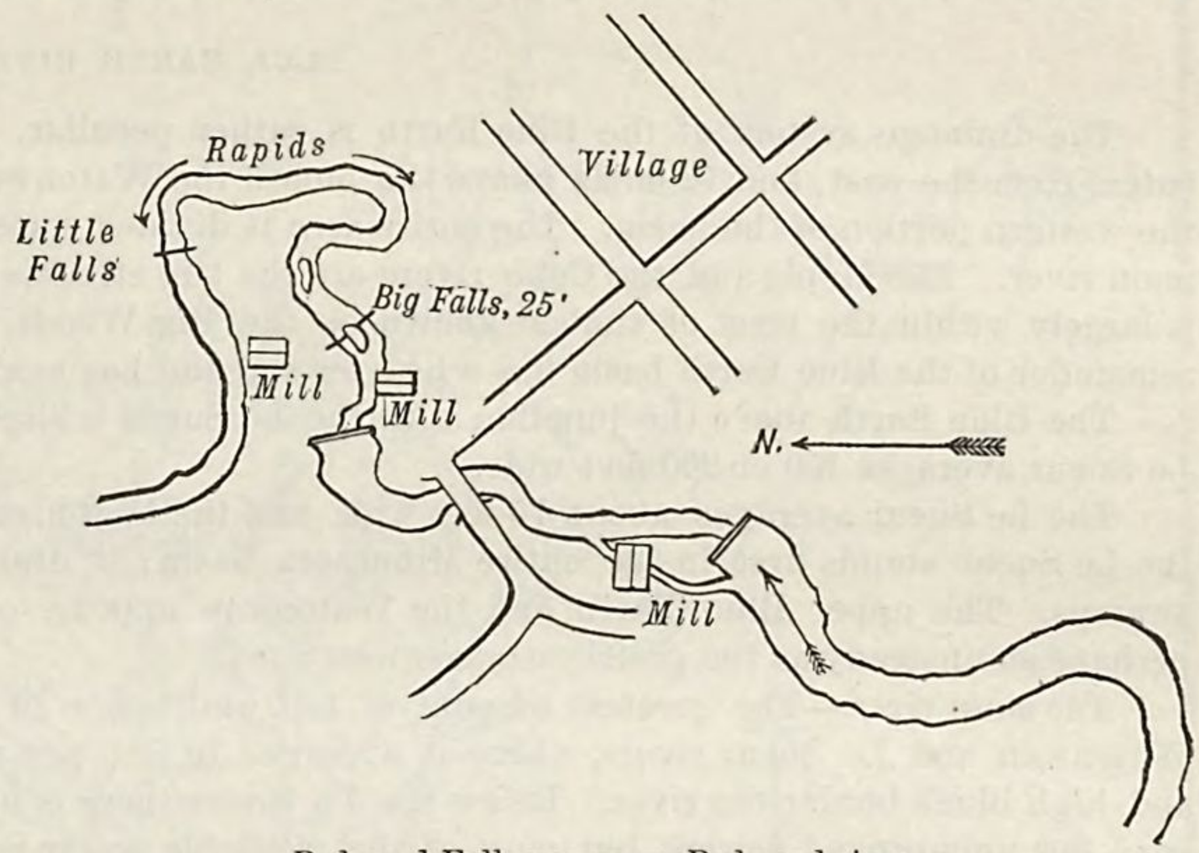
the flow of the river in low seasons, and it is claimed that by building a dam its usefulness in this respect could be increased. The volume of the river is small during severe winter weather, and there seems no reason to believe that as regards regularity of flow it is very much superior to the Yellow Medicine. It is considered good near its mouth throughout the year for three runs of stones under a head of 20 feet, and part of the time much more power can be obtained. There are no important tributaries of the Redwood river. There are altogether seven mills, all flouring- and grist-mills, upon the river—one three-quarters of a mile from the mouth; three at Redwood falls, 2.5 miles above the mouth; one at Marshall, a little more than half-way up the river; another a few miles above; and the last at Lynd, about 6 miles above Marshall.

The first mill on the river has two runs of stones, under a head of 20 feet.

Redwood falls.—It is from these falls that the river gains its chief interest as a water-power stream. In seeking the level of the Minnesota valley the river falls 102 feet within a distance of less than a mile. Its channel runs deep through solid granite, rising in vertical cliffs many feet above the water, or sloping off in steep earth-covered bluffs. Along the cliffs are the wild red cedars, which have probably given the name to the river.

Big falls, with a vertical pitch of 25 feet, and Little falls below, add much to the scenery of this beautiful and unexpected gorge in the prairie. The channel of the river is very winding, and advantage can be taken of this in developing the power.

The village of Redwood Falls, the county seat of the county of that name, is situated upon the right bank of the river, and has railroad connection with the Chicago and Northwestern lines.



Redwood Falls power, on Redwood river.

The upper mill has three runs of stones, working under a head of 20 feet. The pond backs up-stream about 2 miles. The race is cut out of the granite, and the mill has been set down into the rock. This granite is somewhat soft near the surface, and not difficult to remove. The bridge, a substantial structure, spans the river from cliff to cliff about 50 feet above the water. The second mill is situated a short distance below the bridge, and uses two runs of stones, under a head of 20 feet. The pond backs up within 1 or 2 feet of the level in the wheel-pit of the upper mill. The lower mill has a head of 10 feet, and employs two runs of stones. The mill itself is situated on the bluff 100 feet above the river, and the power is transmitted to it by wire rope.

Undeveloped power.—Between the last two mills is an extensive bend in the river and about 65 feet of unutilized fall. In this distance are both of the falls mentioned above and a long stretch of rapids. At Big falls, which is just below the middle mill, is the best power upon the river. Twenty years ago the government had a saw-mill there for the Indian agency, but this is now in ruins. The late owner had intentions of improving the power, but since his death nothing has been done. By cutting a race about 130 feet long across a small bend a head of 40 feet can be obtained. If a tunnel were driven through the neck of land across the large bend, coming out below the lower mill, a head of 75 feet could be gained, but this would of course interfere with the other powers. A dam could be thrown across the river at Little falls, flooding up on the rapids, and a head of 25 or 30 feet could be obtained without interfering with the Big falls power. It is easy to see that only a small portion of the power at Redwood falls is now developed.

Redwood river above the falls.—The three mills above are all flouring-mills. That at Lynd has a head of 22 feet and uses 50 horse-power. The other two use 34 and 18 horse-power, under heads of 11 and 12 feet, respectively.

There are several unimproved sites on the Redwood river in addition to those at Redwood falls. From below the falls to the lowest mill on the river there are several locations. According to the statement of one of the millers, there are two locations affording a head of 20 feet each, and two more of 15 feet each. The banks are high, but consist of clay and gravel. The only unimproved powers of any importance between Redwood falls and Marshall are these: Three miles above the upper mill is a site where a fall of 20 feet is available, and 10 miles above the mill is a locality where, in the winter of 1880–'81, a dam was being constructed to give a head of 12 feet. About 20 miles above Redwood falls is a portion of the river with a rock bed, where a head of 10 feet can be obtained. So far as could be learned these are the only unimproved powers of any importance below Marshall. Any unimproved powers above Lynd must necessarily be small, because of the reduced size of the river.

BIG COTTONWOOD RIVER.

This stream drains an area of nearly 1,000 square miles, and when swollen by melting snow or rain is of large size, but in dry seasons or severe winters it is very much reduced, so that under a head of 10 feet not more than three runs of stones can be used at all times near the mouth; for a large part of the year, however, much more power can be obtained. The bed and banks of the river are of clay and gravel. There are, according to the census returns, only three mills upon the Big Cottonwood, and all are on the lower quarter of its course. They work under a head of 10 feet, and use 12, 56, and 15 horse-power, respectively. All but one of them have two runs of stones each; the exception is a mill at Iberia, which has only one run. There is a number of unimproved sites. One was mentioned, 4 or 5 miles from the mouth, and another at the village of Burns, about 30 miles from the mouth. By building a dam at that place, and carrying the water in a race across a neck of land, a head of 10 feet could be obtained. This would probably give power for two or three runs of stones.

BLUE EARTH RIVER.

The drainage system of the Blue Earth is rather peculiar. Two miles above the mouth the Le Sueur river enters from the east, and 10 miles above the mouth the Watonwan carries into the Blue Earth the drainage from the western portion of the basin. The entire area is divided somewhat equally among these two tributaries of the main river. The Maple and the Cobb rivers are the two streams which drain most of the Le Sueur basin, which is largely within the tract of timber known as the Big Woods, and the soil rather sandy and light, while the remainder of the Blue Earth basin has a heavier soil and has more of the prairie characteristics.

The Blue Earth above the junction with the Le Sueur is slightly larger than the latter stream, and below the Le Sueur averages 150 or 200 feet wide.

The Le Sueur averages about 75 feet wide and the Watonwan about 50 feet. As regards uniformity of flow the Le Sueur stands first in the entire Minnesota basin; it drains the wooded region and also several lakes and swamps. The upper Blue Earth and the Watonwan appear to be about average streams in this respect, not perhaps so unsteady as the prairie streams westward.

The main river.—The greatest amount of fall, and hence of available power, is between the mouths of the Watonwan and Le Sueur rivers, where it averages 10 feet per mile. The bed and banks are largely lime rock, and high bluffs border the river. Below the Le Sueur there is no fall of any importance. Above the Watonwan are a few unimproved powers, but most of the available power is in use. The banks of clay and gravel are there high enough to prevent flowage from the ponds.

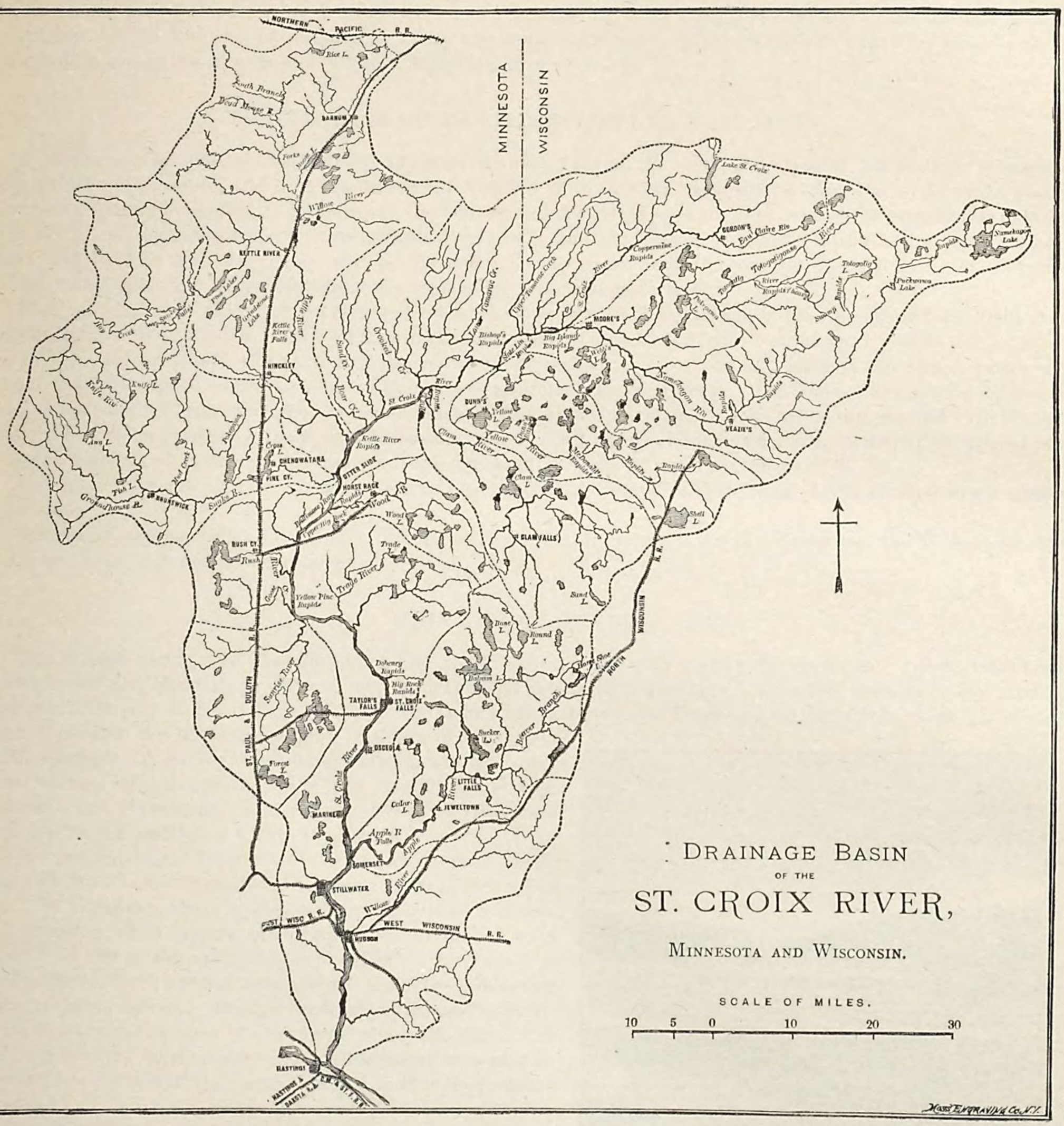
There is only one improved power between the Watonwan and the Le Sueur rivers, although on this portion of the stream a head of 10 feet will furnish power for six runs of stones practically through the year, with only occasionally times when the power would be less. Above the Watonwan about three runs of stones could be worked profitably with a head of 10 feet. There is only one improved power below the mouth of the Watonwan, that is at Rapidan, where the Rapidan Mill Company has a flouring-mill with four runs of stones under a head of 10 feet. The next mill is about 20 miles above the mouth and has three runs of stones under a head of 8 feet. Two miles above, at Vernon Centre, is an old mill with a head of 6 feet and two small runs of stones. About 5 miles above Vernon Centre are the Champion mills with three runs of stones under a head of 6 feet. Five miles above is a mill with three runs of stones under a head of 7 feet. About the same distance above the last mill is one opposite Winnebago City with a head of 10 feet and three runs of stones. Above Winnebago City is a mill with two runs under a head of 6 feet, then a small mill of only one run, and, finally, 1 mile below Winnebago City, a mill of two runs under a head of 6 feet.

Le Sueur river.—There is not so much fall in this stream as in the Blue Earth. The Maple and the Cobb rivers, its large tributaries, enter within 4 or 5 miles of the mouth. On the lower part of the river six runs of stones can be profitably worked under a head of 10 feet throughout the year. In the latter part of 1880 the Red Jacket mills were burned down, which were situated near the mouth of the river. They had four runs of stones under a head of 9 feet, but could have obtained a head of 11 feet.

There is an old saw-mill, with a head of 8 feet, a few miles above the Cobb river, and that is the only mill upon the stream, though there are some undeveloped powers.

Of the two chief tributaries of the Le Sueur the Cobb river is small and unsteady and has no developed powers. The Maple, likewise, is limited in power. The only mills of much importance are the Maple River mills, which have three runs of stones and two wheels under a head of 14 feet, rated at about 60 horse-power. Steam is used during low water. At Mapleton, near the head of the river, is a mill which takes the water from an artesian well in addition to the flow of the river itself.

Watonwan river.—This river is not so large as the Le Sueur, but stands next to the Blue Earth in importance as regards improved power. As regards uniformity of flow it has much the same general characteristics as the Blue Earth, and there are times in which it is impossible to run the mills; but with a head of 10 feet it can be depended upon to give power for three runs of stones nearly all the year. The bed and banks are of clay and gravel, and the banks are high enough to restrict the ponds to the river-channel.



Drainage Basin of the St. Croix River,

Minnesota and Wisconsin.

SCALE OF MILES.

10 5 0 10 20 30

Hoen & Engraving Co. N.Y.

There are five mills upon the Watonwan. The first is 3 or 4 miles from the mouth, a three run mill with a head of 8 feet. At Garden City, about 5 miles above the mouth of the river, are two mills. The lower one has three runs of stones under a head of 7 feet, and the upper one three runs under a head of 8 feet.

At Watonwan, about 3 miles above, is a mill with one run of stones under a head of 7 feet, and the last mill on the river is one at Medalia, some 10 miles above Watonwan. It has two runs under a head of 11 feet. There are a number of unimproved powers.

Two miles above Garden City is a site where, by constructing a low dam and running a race across a neck of land, a head of 10 feet can be obtained. There are, apparently, many places where it would be practicable to throw a dam across the stream and obtain a moderate head of water.

TRIBUTARIES OF THE MISSISSIPPI IN WISCONSIN.

A glance at the map shows that all the western and most of the central portion of the state of Wisconsin drain into the Mississippi, and that the prominent features of the system of drainage are three large streams—the Saint Croix (partly belonging to Minnesota), the Chippewa, and the Wisconsin. These are the largest three rivers of the state, and on account of their geographical relations, and the general similarity in the topography of their basins, and in their hydrology, they will be discussed in the order given, previously to considering the smaller streams which enter the Mississippi from the west below the Minnesota river.

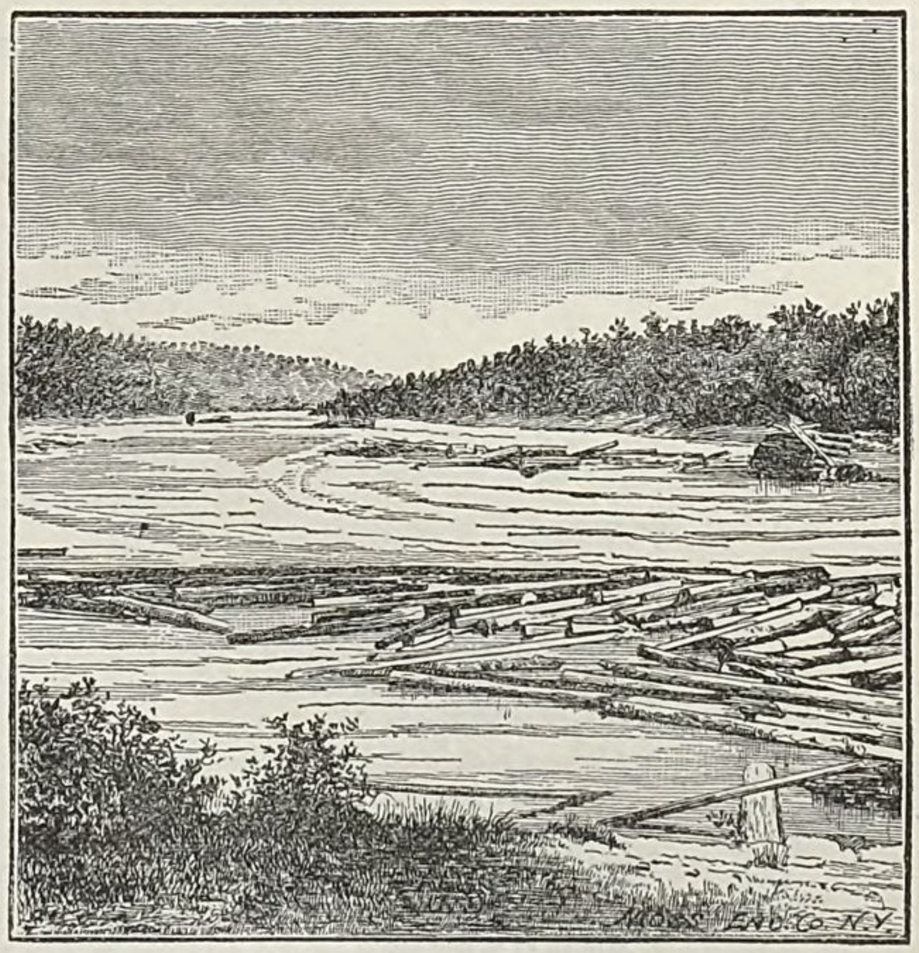
They are similar in rising on the elevated ridge which separates the drainage of lake Superior from the waters running to the gulf of Mexico. They all flow in the same general direction, a little west of south, across the Archæan base of the continent, into the region of the sedimentary rocks. On this account, largely, the upper waters are characterized by rapids, while the slope of their lower sections is more uniform. The sources are in wild regions of lakes, tamarack and cedar swamps, and sand ridges. The upper portions of their basins are covered with timber, largely pine, which gradually disappears in passing south, until finally the hardwood also is limited to groves and the lower portions of their basins assume in part the characteristics of a prairie region.

The great industry on each of these streams has been lumbering, and their basins have yielded much wealth to the state.

Because of the position of the Black River basin, wedged in between the Chippewa and the Wisconsin, that stream has been included in its order of occurrence.

SAINT CROIX RIVER.

This stream ranks with the Chippewa and the Wisconsin as being among the prominent tributaries at the headwaters of the Mississippi. The mouth is on the east side of the Mississippi, 557 miles from its source, and 29 miles below the city of Saint Paul. The source is in what is known as Upper lake Saint Croix, near the divide which separates the drainage of lake Superior from that of the Mississippi. The river is 168 miles long, and in the lower three-quarters of its course forms the boundary between Minnesota and Wisconsin. The drainage area is 7,576 square miles, the larger part lying within Wisconsin.



The Saint Croix river, from above Taylor's falls.

The two important tributaries in Minnesota are the Kettle river and the Snake river, draining about 1,000 square miles each. In Wisconsin there is one large tributary, the Namecagon, draining 1,025 square miles, and several others with basins from 200 to 400 square miles in extent.

The Saint Croix flows almost exclusively in the lumbering region of the northwest. Being a wooded region, not as inviting to settlers as the open prairie found along the Minnesota river, the country is comparatively a wilderness; it is only in the southern portion of the basin that the land is much cultivated.

The Saint Paul and Duluth railroad runs north through the basin in Minnesota, and the Northern Wisconsin is partly constructed from near the mouth of the river northeast toward Bayfield, on the shore of lake Superior; but these roads have done little as yet toward the settling of the country through which they run.

Lumbering has been the one business of the entire region, but, at the present rate, the cutting of pine will cease to be profitable in the course of from fifteen to twenty-five years. There are several towns upon the lower part of the river, as Stillwater, Hastings, and Taylor's Falls, which owe their prosperity in the past to the lumber trade and

which are already too well established to be ruined by its decline. Taylor's Falls is one of the oldest towns in Minnesota, having been settled in 1837; and Stillwater, 25 or 30 miles farther down the river, was settled in 1843.

Character of the soil and timber.—Although so largely woodland there is a wide difference between different sections of the Saint Croix basin; and this is due to the varying nature of the soil. This is entirely drift, but differing in character. A large part of the basin is till, consisting largely of clay soil, and supporting a growth of hardwood, interspersed with pine; but passing northeast through the basin, bounded on the west by the river itself is a tract of land 10 or 15 miles wide, extending almost to the shore of lake Superior, and consisting of a light, sandy soil. On this is a worthless growth of pitchy pine, scrub-oak, and poplar. Half way up the river, in Wisconsin, the timber is chiefly hardwood, with perhaps one acre of pine to ten acres of other kinds of timber. Above the Wood river "the barrens" occupy all the lower portions of the tributaries on the east side of the river, but farther back, upon the headwaters of these tributaries and their branches, is found valuable pine timber, interspersed with hardwood and inferior qualities of soft wood. On the west side of the Saint Croix there is little pine timber until the region of the Snake and Kettle rivers is reached. On these streams and their tributaries are valuable pine lands.

In the region east of the Kettle river and north of the Saint Croix there are indications that a great fire occurred years ago. It is said that by digging up the soil coals can be found. No valuable pine is found, but the land is covered by a second growth of small pine, cedar, spruce, poplar, etc.

Flow of the streams.—The wooded character of the basin, the many lakes, and tamarack and cedar swamps, and the light sandy nature of so much of the soil, are all favorable to a steady distribution of the flow of the streams. The result is that the Saint Croix ranks with the Chippewa and the Wisconsin as being one of the three steadiest tributaries of the Mississippi, omitting some minor branches at the extreme headwaters of the Mississippi. Its ordinary low flow is about 0.37 cubic foot per second per square mile.

The sandy region, with the impervious substratum at the extreme upper waters of the river, especially, is very marked in its action. There are scarcely any streams in it, and this is because the water immediately sinks below the surface, reappearing in steady flowing springs along the rivers. Thus, the lake which gives rise to the Saint Croix river, a sheet of water some 4 miles long by one-half mile wide, is fed by many springs coming out of its banks, besides numbers bubbling through its bed.

Because the water gradually seeks the streams through the ground, they are very uniform in their flow; also, as the loss from evaporation is small under these circumstances, the total flow for the year bears a high ratio to the rainfall.

In the accompanying tables the average flow per square mile for the entire basin is used in calculation for the different sections. This, of course, can give only approximate results, as must be evident from the preceding remarks regarding the topography, but time does not permit a more complete application of the ratios of flow for different kinds of country deduced in treating of the entire Mississippi basin. It is not probable that the results obtained differ very greatly from the true amounts.

Table of fall, flow, etc., of the Saint Croix river.

Station.	Distance from preceding station.	Distance from the source.	Intermediate fall.	Total fall from the source.	Drainage area above station.	Flow per second past station.		Theoretical horse-power under 10 feet head.	
						Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Miles.*	*Feet.*	*Feet.*	*Sq. miles.*	*Cubic feet.*	*Cubic feet.*	*H. P.*	*H. P.*
Source	.....	.....	.....	0	.....	.....	.....	.....	.....
Above mouth of Eau Claire river	6½	6½	2	2	117	47	96	53	109
Mouth of Eau Claire river	0	6½	2	2	224	83	183	94	208
Copper Mine rapids	.....	.....	.....	.....	366	135	299	153	339
Mouth of Namecagon river	.....	38	100	102	1,451	537	1,187	609	1,347
Mouth of Yellow river	12	50	20	122	2,084	771	1,705	875	1,934
Above mouth of Clam river	12	62	22	144	2,428	898	1,986	1,019	2,253
Mouth of Clam river	0	62	0	144	2,844	1,052	2,326	1,193	2,639
Above mouth of Kettle river	11½	73½	50	194	3,046	1,127	2,492	1,279	2,827
Mouth of Kettle river	0	73½	0	194	4,139	1,531	3,386	1,738	3,841
Mouth of Snake river	4½	78	26	230	5,097	1,886	4,169	2,140	4,730
Mouth of Wood river	6	84	.....	.....	5,281	1,954	4,320	2,217	4,901
Mouth of Sunrise river	16	100	.....	.....	5,857	2,167	4,791	2,458	5,435
Saint Croix rapids	20	120	111	341	6,202	2,295	5,073	2,604	5,755
Mouth of Apple river	18	138	.....	.....	6,951	2,572	5,686	2,919	6,451
Mouth of Willow river	13	151	.....	.....	7,301	2,700	5,972	3,063	6,775
Mouth of Saint Croix river	17	168	.....	.....	7,576	2,800	6,197	3,176	7,030

Table of tributaries of the Saint Croix river.

River.	Length (map measurement).	Drainage area.	Discharge per second.		Theoretical power under 10 feet head.	
			Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Sq. mls.*	*Cu. feet.*	*Cu. feet.*	*H. P.*	*H. P.*
Saint Croix above Eau Claire river	7	117	47	96	53	109
Eau Claire river	25	107	40	88	45	101
Namecagon river	85	1,025	379	838	430	951
Yellow river	50	310	115	254	130	287
Clam river	50	416	154	340	175	387
Kettle river	70	1,093	404	894	458	1,014
Snake river	78	937	347	766	394	869
Wood river	30	168	62	137	70	155
Sunrise river	30	292	108	239	122	271
Apple river	55	427	158	349	179	396
Willow river	35	246	91	201	103	228

Reservoir system.—In connection with the "reservoir system" for improving the navigation of the upper Mississippi, 14 sites have been surveyed and found practicable for reservoirs within the Saint Croix basin. The estimated cost of their construction is about $430,000, and it is estimated that by means of them an addition of 2,600 cubic feet per second can be made to the low flow of the river during 120 days of low stage. This would nearly double the ordinary low-water discharge of 2,800 cubic feet per second, and would have nearly as great an effect upon the water-powers as it has been shown would take place on the upper Mississippi above the Minnesota river by the introduction of the "reservoir system" in that region.

Water-powers of the basin.—According to the records of the United States engineers, the lake which forms the source of the Saint Croix is at an elevation of 1,010 feet above the sea. This makes the total fall of the river to its mouth 344 feet, and the average slope 2.05 feet per mile. The slopes of the tributaries vary from 3 to 6 feet or more per mile. On account of these very considerable slopes, there is much water-power in the Saint Croix basin which will be utilized when farms and population bring into that region a demand for manufacturing.

The water-power sites are not limited to the subordinate streams. On the Saint Croix itself are numerous rapids, and in the lower portion of the river, below where the large branches add their flow, are the Saint Croix rapids, a fine site, where a fall of between 30 and 40 feet awaits improvement.

There are a few powers in use upon the lower tributaries, especially on the Apple river, but none upon the main river. There are, however, between 60 and 70 dams within the basin, built for the purpose of flushing logs into the main stream from the smaller ones. In the driving season the gates are opened and the logs float down upon the full current. The frequent occurrence of these dams indicates the undeveloped powers of the rivers.

The isolation of the upper portion of the river rendered all personal examination there impracticable, and the following brief description was obtained mainly from old lumbermen familiar with the entire country.

THE MAIN RIVER.

For the first 23 miles, up to Stillwater, the river averages about half a mile wide and the current is slight. The upper portion of this expansion is called lake Saint Croix. At Stillwater the bluffs rise steep on both sides to the height of 150 or 200 feet. About three-quarters of a mile above the town the lake ends and the river assumes its normal width. The head of navigation is at Taylor's falls, at the foot of Saint Croix rapids, about 50 miles above the mouth. The river mostly flows in a valley bounded by bluffs, with a flat on one side or the other. As a general thing it keeps close to the left or east bluff, and the right bluff is from 1,000 to 3,000 feet distant. The rapids in the river are generally over rock, while gravel, clay, and sand form the bed in the still stretches of its course.

From the outlet of upper lake Saint Croix down to the mouth of the Eau Claire, a distance of 6.5 miles, there is only a fall of 2 feet in the river. From thence to what is known as the Big dam (logging dam), a distance of 8.5 miles, there is about 7 feet of fall. In the next 23 miles, to the mouth of the Namecagon river, there is a descent of 93 feet, or 4 feet per mile, and many rapids occur, among which Copper Mine rapids may be mentioned.

Above the mouth of the Namecagon the ordinary low-flow power under a head of 10 feet is at least 150 theoretical horse-power.

The Namecagon is the second in extent of drainage area of all the tributaries, and when it enters the main river it increases the power of the latter, under a head of 10 feet, to 600 theoretical horse-power, with the ordinary low flow.

In the 12 miles from the mouth of the Namecagon to the mouth of the Yellow river, the total fall is 20 feet. Names have been given to three rapids within that distance, namely, Big Island rapids, State Line rapids, and Bishop's rapids. Each of the first two is described as affording fine opportunities for developing water-powers. At Big Island rapids the river runs close to the bluffs on the left bank, but a dam would need to extend some distance across the flat on the right.

From the mouth of Yellow river down to the head of Kettle rapids, a distance of 21 miles, the average slope is 1.8 foot per mile, and the river is good for logging, there being no rapids of special importance. It is very probable, however, that available water-power sites can be found in that section.

Kettle River rapids.—The Kettle River rapids are, next to the Saint Croix rapids, the most prominent on the river. They start 2.5 miles above the mouth of Kettle river, which enters from the west, and end 1.5 mile below it. In this length of 4 miles the total fall is 49 feet, of which 34 feet is above the mouth of Kettle river. Two islands from 1 mile to 2 miles long divide the river into two channels. The bed of the river is solid rock, and it is practicable to build several dams. As to the best method of improving the power it is impossible to speak without examination of the locality. Above the mouth of the Kettle river a head of 10 feet would afford 1,280 theoretical horse-power, with the ordinary low flow; and below the entrance of the Kettle river 1,737 theoretical horse-power, under the same conditions of flow, according to the estimates previously described.

Above the mouth of the Snake river, which enters 4.5 miles below the Kettle river, there is 11 feet of fall from the foot of the rapids.

Below the river, down to Saint Croix rapids, there are the following rapids, which have received names: The Otter Slide, just below the mouth of the Snake, the ordinary low-water power of which, under a head of 10 feet, is 2,140 theoretical horse-power; the Horse Race, 1 mile below; the Baltimore rapids, a mile below the mouth of the Wood river, the ordinary low-water power of which, under a head of 10 feet, is 2,220 theoretical horse-power; the Upper Big Rock rapids, about 1 mile below them; and the Yellow Pine rapids, about 3 miles above the mouth of Sunrise river. The amount of fall at each of these rapids cannot be determined from the data at hand.

Baltimore rapids were described as offering advantages for development. Yellow Pine rapids are 2 miles long and not very heavy. The total fall from the mouth of Snake river to Saint Croix rapids is 111 feet, and the average slope is 2.64 feet per mile. This must afford opportunities to develop power with what will be a reasonable expense at some time in the future. At the Horse Race the river runs close to the eastern bluff, and it would be necessary to extend a dam some distance across the flat on the west bank if a high head were utilized. Very probably the same would be necessary at most sites along the river.

Saint Croix rapids.—The Saint Croix rapids offer fine opportunities for water-power, and were used at one time, but now the river flows unemployed. There is a total descent of 55 feet in the 6 miles, which may be included under the name of Saint Croix rapids. Several local names are indefinitely applied at different points. At the foot are Taylor's falls, about three-quarters of a mile above are Saint Croix falls, then Tuttle's falls, etc. Strictly speaking there are no falls in the entire distance, only a more rapid decline in the bed at certain places.

The village of Taylor's Falls is situated in Minnesota, at the foot of the rapids, about 50 miles above the mouth of the river, at the head of navigation. Saint Croix Falls, a village of Wisconsin, is situated upon the slope overlooking the river from that side, nearly opposite Taylor's Falls.

Directly below the rapids the river enters the Dalles of the Saint Croix, where for half a mile or more it passes between vertical cliffs of trap-rock with sharp edges and bold angles. Just above the entrance into the Dalles the waterway is so contracted that when the river is high the water forms a fall of nearly 5 feet before it can overcome the resistance, but there is no very rapid descent there in low water. It is to this portion of the river that the name of Taylor's falls is given. Above the Dalles the rock continues in the bed, and to a certain extent in the banks of the river, but the valley spreads out considerably.

On the Minnesota side the bank rises steep from the river for 30 or 40 feet at the lower part of the rapids; back from this for several hundred feet is a nearly level plain, swampy in places, and bounding this are the bluffs, rising fully 100 feet higher. At the foot of the rapids the plain narrows and is lost in the Dalles. On the Wisconsin side, in the vicinity of Saint Croix falls, the slope is rather more uniform up to the general level of the country. At the entrance into the Dalles the river is scarcely more than 100 feet wide. At Saint Croix falls, three-quarters of a mile above Taylor's falls, it is between 200 and 300 feet wide, the average width of the river in this part of its course.

The portion of the rapids known as Saint Croix falls presents the most favorable site for improvement of the power, and here a dam was once built and saw-mills were run. The bed is solid rock, and the banks rise abruptly from the river on both sides. On the Minnesota side a large, high mass of trap-rock stands out in the channel, and forms a natural abutment for a dam; on the Wisconsin side the rock bank rises to a considerable height above the water in a rib, and back of it is a depression which leads to the slope upon which the village of Saint Croix Falls is situated. The improvement, long since gone to ruin, consisted of a dam built across the river at the point described, and a race blasted through the rock in the line of the depression on the Wisconsin side, and then carried down the slope along the river front, giving a head of 25 or 30 feet. The dam was a very extensive structure, raising the water to a height of 25 feet when in good condition. It was 300 feet long, 24 feet wide at the top, and

only 60 feet wide at the base. Wedge-shaped log cribs were built in the stream with spaces between them; similar cribs were built up-stream and floated down into these spaces, until finally only the central space was left open, through which the river flowed. The two cribs on each side of this space were built with shoulders projecting against the current. Finally a crib built accurately, with corresponding shoulders to fit into this space, was floated down into place, and the channel was closed. The crib-work was planked over. The dam was not cared for, the planking and crib-work were partly destroyed, a portion being cut away to make a passage for logs, and finally the whole dam was washed away.

The same natural facilities exist for developing this water-power as formerly, but the interests upon the two sides of the river are owned by different persons, and there will be some difficulty in coming to an agreement. If the dam were built so as to give a head of about 40 feet, which is practicable, a race could be carried down the plain on the Minnesota side for a long distance as readily as on the Wisconsin shore. The pond would probably back water 4 or 5 miles, and would not overflow much land.

With the ordinary low flow the power under a head of 30 feet is 7,811 theoretical horse-power, and under a head of 40 feet 10,415 theoretical horse-power. With the yearly average flow it is 17,266 theoretical horse-power under a head of 30 feet, and 23,021 theoretical horse-power under 40 feet.

There is about 5 feet of fall in the river from the site of the dam to Taylor's falls. Here is an excellent site for the construction of a dam, which would scarcely be more than 100 feet long, but the vertical cliffs come close to the river just below, leaving only room for a small steamboat landing, without space to erect extensive manufactories.

TRIBUTARIES OF THE SAINT CROIX RIVER.

As they are mainly in the almost uninhabited woods, very little information can be obtained about the water-powers of the tributaries of the Saint Croix. Nearly all of them are known to have considerable descent, and because of the wooded, swampy character of the land, as well as the sandy nature of much of the soil, they have in the main a very steady flow throughout the year.

As has been previously mentioned, the general average for the entire basin has been assumed for each tributary, and hence in making the calculations 0.37 foot per second per square mile has been taken as the ordinary low flow. That it may be over 0.40 of a cubic foot per second per mile for some of the streams at the headwaters is probable, and then again it may fall below the average in the case of several streams tributary to the lower portion of the river.

When the country is settled so as to create a demand for water-power, the woods will be largely cleared away, the swamps drained, etc., and this will tend to diminish the steadiness of flow, so valuable a consideration in questions of this kind.

The Namecagon, Kettle, and Snake rivers present the largest powers, and as the Namecagon drains almost entirely from the sandy region called "the barrens", it is probably one of the most steady rivers of the entire system. The Kettle and Snake rivers drain extensive regions of tamarack swamps and woods, which cannot fail to have a great influence upon the flow.

NAMECAGON RIVER.

The United States engineers' reports state that the average slope of the Namecagon is about 5 feet per mile, and as the length is 75 or 100 miles, the total descent is, according to this estimate, not far from 500 feet. From the source down to Vezies, which is about 25 miles above the mouth, "the river is generally narrow and rapid, stretches of rapids over native trap-rock being frequent. There are also several vertical falls of from 2 to 4 feet." "From Vezies to the mouth the river is from 100 to 200 feet wide, and there are several sharp pitches and rapids, the principal of which are Little and Big Ball rapids, and Dupee flats."

The descent appears to be rather uniformly distributed, considering the entire river. There is a descent of 40 feet in the first 12 miles above the mouth of the Totogatic, and in the first 6 or 10 miles above Vezies there is at least 30 feet of fall. The source of the Namecagon river is a lake some 10 square miles or more in extent, having the same name. The lumbermen have a dam affording a head of about 7 feet just below the outlet of the lake, which floods the lake and stores sufficient water to "drive" for about three weeks. There is also a logging dam below Little Pequayon (*a*), and one called the Hanscomb dam about 2 miles above the Chippenazy creek.

The Totogatic is the largest tributary to the Namecagon, and lying to the north of the main stream drains over one-third of its entire basin. It enters the Namecagon about 5 miles from its mouth. The course is very winding, and in it there is considerable inequality of slope. There are three dams upon the river, the lowest some 12 or 15 miles below the source, and in this distance there are some slight rapids. From the lower dam down to the mouth of the Totogatic Ouse (Little Totogatic), a distance of 10 miles, there are heavy rapids. In this section are the Upper and the Lower falls, 6 miles apart, with rapids between. There is a vertical pitch of 10 feet over ledges of trap-rock at the Upper falls and at least 8 feet at the Lower falls. Below these is the Horse Race. The United

a Pequayon is the Chippewa for "dead-water."

States engineers' reports state that in this 10 mile section the river is entirely unnavigable for boats of any kind. Below the mouth of the Totogatic Ouse the river is good for logging and not so rapid; there are rapids however, especially in the lower part of the distance. In the last 10 miles of the river the fall is 40 feet.

The other tributaries of the Namecagon are all small, but have a rapid descent. Thus McKenzie's creek, which drains three lakes, has a fall of 33 feet in the last 2.5 miles, and the Chippenazy creek is crowded with logging dams, indicating a rapid fall to the main river.

KETTLE RIVER.

The Kettle river is described by the United States engineers as having "an average fall of 6 or 8 feet per mile over sharp pitches and long stretches of rapids. The banks are high and precipitous and the valley is narrow". For 7 miles above the mouth there are rapids, and then about 10 miles of slack-water. Above that, for some 14 miles, there are alternately rapids and quiet water. Then there is a long stretch of rapid water, and near its upper portion are Kettle River falls, with a vertical pitch of 12 feet. From these rapids up to the mouth of the Moosehorn river, there is quiet water nearly all the way, and above that are more or less rapids, but the stream becomes small and of little importance so far up. The Saint Paul and Duluth railroad crosses the river at a settlement called Kettle River, and the Northern Pacific railroad crosses the headwaters.

SNAKE RIVER.

The Snake river is not as large as the Kettle river, but has a rapid descent in places. From the mouth up to the Chengwatona dam, a distance of about 14 miles, the average slope is 11 feet per mile, and there are "almost continuous rapids over trap-rock ledges and bowlders".

Just above Chengwatona dam is Cross lake, and a few miles above, Pokegama lake, both flooded by the dam, which is used for driving logs over the rapids below into the Saint Croix. It is owned by persons in Saint Paul, who charge a toll of 10 cents per 1,000 feet passing the gates. The head is from 8 to 9 feet, and at a cost estimated to be $15,000 might be increased to 13 feet. This would flood up the river to Brunswick, a distance of 24 miles.

Above Brunswick the river is rather sluggish for 20 or 30 miles, but above that there are many rapids, including Snake River falls with a vertical pitch of 8 feet. The rapids in the river are over solid rock or bowlders, and the banks are composed mainly of yellow clay or of sand and gravel. The side streams are mostly narrow and rapid. The Groundhouse, entering at Brunswick, is the principal tributary. Upon it is a grist- and saw-mill, using about 20 horse-power under a head of 6 feet.

YELLOW RIVER.

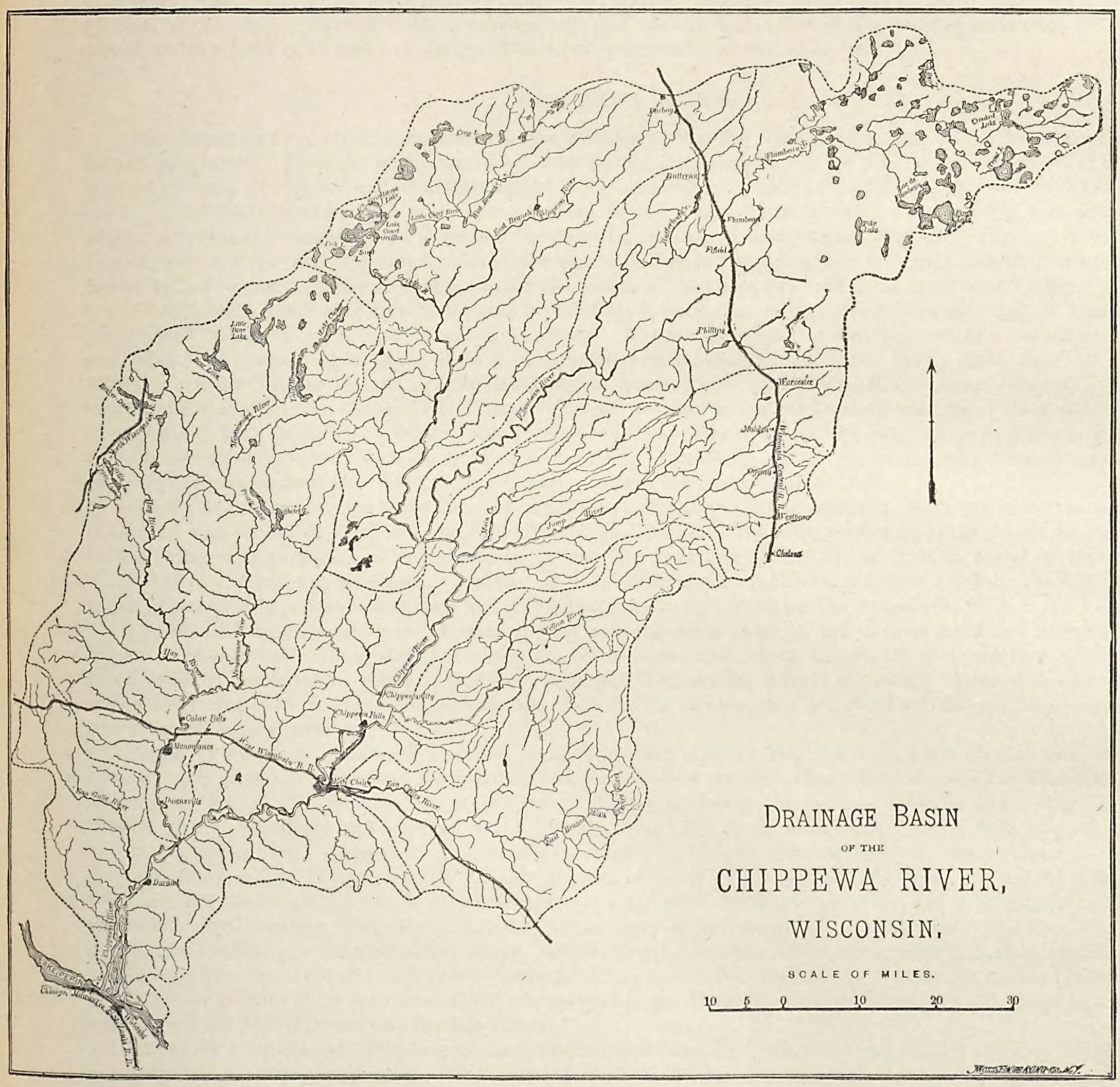
The Yellow river is a very steady stream, draining 310 square miles of the barrens. Several lakes, notably Yellow lake, near the mouth, tend to regulate the flow. The stage varies through the year only from 1.5 foot to 3.5 feet, according to the locality. There are a number of rapids on the stream and many practicable water-power sites are to be found. From Yellow lake the rapids are described as almost continuous down to the mouth of the river, a distance of 10 or 15 miles. There are four logging-dams upon the river, one flooding Yellow lake.

CLAM RIVER.

The Clam river, draining 416 square miles, is formed by two branches, the North fork and the South fork, which unite at the head of Clam lake. At the foot of this lake is a dam which stores water sufficient to drive logs to the mouth of the river. There are rapids below the junction, and many opportunities for developing water-powers. Above the junction, on both branches, there are rapids and dams used for logging. On the South fork are the Clam falls, where there is a head of 15 feet, of which 6 or 8 feet has been used by a saw-mill.

APPLE RIVER.

The Apple river flows through a comparatively settled region and has several improved water-powers. A large amount of lumber is still brought down from the upper waters, and there are a number of dams used for driving. The area drained by the Apple river is 427 square miles. At the headwaters are ten lakes, one of them 6 miles long and from one-half to three-quarters of a mile wide. There are a large number of water-power sites available. According to the statement of a person familiar with the river the first improved power is at Somerset, 5 or 6 miles above the mouth of the river. There is at that point a flouring-mill and saw-mill with a head of 10 feet. At Jewelton, some 15 or 20 miles up the river from the mouth, there are two flouring-mills and a saw-mill under a head of 10 or 12 feet, and a few miles above are a flouring- and saw-mill with about the same head of water. These are the only mills upon the river. Between the two last mentioned powers is a fine unimproved power, but the largest is at Apple River falls below Somerset. These falls have been a source of considerable expense to the lumbermen in the effort to improve them for driving. By cutting a canal across a bend in the river a head of about 35 feet could be obtained.


DRAINAGE BASIN
OF THE
CHIPPEWA RIVER,
WISCONSIN.
SCALE OF MILES.
10 5 0 10 20 30
Hurley
Butternut
Flambeau
Fifield
Phillips
Worcester
Medford
Westfield
Chelsea
Crooked Lake
Pike Lake
Little Tiger Lake
Bear Lake
Beaver Dam L.
Hay River
Menomonee River
Chippewa River
Yellow River
Jump River
Flambeau River
Chippewa City
Chippewa Falls
Cedar Falls
Menomonee
Eau Claire
Eau Claire River
Durand
Chippewa River
Chicago, Milwaukee & St. Paul R.R.
Dubuque

SMALLER TRIBUTARIES.

The Sunrise river, Willow river, Wood river, etc., have mills upon them, but it is evident from their number that the resources of these streams for small powers are not exhausted. The only power used on the Sunrise is at Sunrise City, a few miles above the mouth. There are two flouring-mills under heads of 9 and 12 feet, respectively, and a saw-mill under a head of 12 feet.

According to the census returns, there are two small flouring-mills and two saw-mills on the Wood river, and one flouring-mill on the Trade river, a little stream which enters below.

The Willow river, which flows into the Saint Croix near its mouth, is the most extensively improved of all the streams of the basin. Upon it are five flouring-mills and one saw-mill. One of the flouring-mills uses 195 horse-power under a head of 16 feet, and another 150 horse-power under a head of 12 feet.

CHIPPEWA RIVER.

The Chippewa river extends southwest across Wisconsin, from the border of Michigan to the Mississippi at the foot of lake Pepin. The river has its utmost sources on the divide separating the drainage of the great lakes from that of the gulf of Mexico, and after flowing 165 miles enters the east side of the Mississippi, 611 miles below its source. The 9,573 square miles of territory drained by the Chippewa is situated chiefly in the wild, unsettled region of northern Wisconsin, and resembles the Saint Croix basin in being a great lumbering region. Millions of feet of pine are cut every year and sent down the stream, either to be manufactured by mills situated on the river, or else rafted to points on the Mississippi below the mouth of the Chippewa, and there made into lumber.

As with other lumbering rivers, the pine of the Chippewa region is fast being cut away, and the camps are now located far up toward the headwaters of the stream. The settled portion of the basin proper is the southwestern end, where the wooded region gives place to the prairie which extends west to the Rocky mountains. The only railroads are the Chicago, Saint Paul and Minneapolis, crossing the river at Eau Claire, about 50 miles from the mouth, and the Wisconsin Central, which has two branches, one passing northward across the sources of the river to Ashland on lake Superior, the other passing west to the Chippewa river at Chippewa Falls, about 10 miles above Eau Claire, where it connects with the first-mentioned road. Eau Claire and Chippewa Falls are the most prominent towns of that region, and have owed their prosperity in the past to the lumber trade.

The settled portion of the basin does not extend very far above Chippewa Falls. East and north the country is covered with timber of various kinds, including pine. The soil is the drift, consisting of clay, sand, and gravel. In some places arenaceous soil predominates. There is no marked distinction, such as is found in the sandy "barrens" of the Saint Croix region. The fact of the growth of pine indicates a lighter soil than the stiff clay of the prairie, and it is probable that sand and clay occur irregularly associated throughout the basin.

The wooded region consists very largely of tamarack and cedar swamps, and in them are found large amounts of peat. Interspersed throughout this region are many lakes, upon which the growth of vegetation has not yet made sufficient advances to convert them into swamps. The country is level or rolling. Toward the south the streams have cut deep into the drift, but northward, about the sources, they are small and have not yet worn their way much below the surface.

System of drainage.—The main line of drainage runs very nearly along the central line of the basin, but the name of the river is not given to this continuation of the principal stream. The stream divides 112 miles above the mouth; one branch, the prolongation of the line of drainage, rises in the extreme lakes on the border between Wisconsin and Michigan, and is called the Flambeau river; the other flows more directly from the north and receives the name of the Chippewa. The Flambeau drains 1,983 square miles, while the main stream above the junction drains only 1,777 square miles. About 56 miles above the Flambeau the Chippewa again divides into the West and East branches, the one flowing from the north, the other from the northeast, and draining, respectively, 480 and 278 square miles. The chief tributaries, in the order of their occurrence, are the West and East branches, the Courte Oreille, the Flambeau, the Jump, Yellow, Eau Claire, the Menomonee, and Eau Sale rivers. The Menomonee flows nearly south, and enters the main stream about 23 miles from its mouth. It drains 1,957 square miles, and on account of its peculiar position a large part of the drainage of the Chippewa river does not reach that stream until near its entrance into the Mississippi.

Fall of the streams.—At Chippewa crossing, where the Wisconsin Central railroad crosses the East branch, the water surface is 1,509 feet above sea-level, and as the mouth of the river is 660 feet above the sea there must be nearly 900 feet of total fall in the river, or about 4.5 feet per mile. From the junction of the two branches down to the mouth the total fall is 621 feet, and the average slope 3.76 feet per mile. This is a heavy fall, and causes many rapids in the course of the river. The tributaries likewise abound in rapids, but from the scarcity of elevations obtainable for them and the main stream I can only state the existence of a great deal of rapid water. These rapids give rise to a large amount of water-power which will be available when the country is settled and the wants of the population are to be met, but at present these powers are wasted, with the exception of one on the main river at Chippewa Falls, yet to be described, and a few improved sites on some of the lower tributaries. There is very little prospect of the rapids being improved at the upper waters of the basin for many a year to come.

Flow.—The comparatively uniform surface of the country, and its covering of timber, together with the lakes and swamps, tend to prevent the rapid escape of the water into the streams, and maintain the Chippewa, even in ordinary low flow, at an average of about 0.37 cubic foot per second per square mile. For the same reasons as in the case of the Saint Croix, the average for the entire basin has been used throughout in estimating the discharge of the tributaries, although more or less difference must exist between them in their ratios of flow. Streams like the Flambeau or the Courte Oreille, which drain many lakes and swamps, are in all probability more steady in their flow than the Thornapple and Yellow rivers, with their long, narrow basins, or the streams coming from the less wooded region in the southern end of the basin.

Table of distances, flow, etc., of the Chippewa.

Station.	Distance from preceding station (approximate).	Distance from the junction (approximate).	Drainage area above station.	FLOW PER SECOND PAST STATION.		THEORETICAL POWER UNDER 10 FEET HEAD.	
				Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Miles.*	*Sq. miles.*	*Cub. feet.*	*Cub. feet.*	*H. P.*	*H. P.*
Junction of the East and West branches	.....	0	757	280	692	318	785
Mouth of Courte Oreille river	14	14	988	366	916	415	1,039
Above mouth of Thornapple river	22	36	1,383	511	1,282	580	1,464
Above mouth of Flambeau river	17	53	1,777	667	1,647	757	1,869
Mouth of Flambeau river	0	53	3,761	1,392	3,486	1,579	3,955
Mouth of Jump river	7	60	4,606	1,704	4,270	1,933	4,844
Above mouth of Yellow river	30	90	4,926	1,823	4,566	1,068	5,780
Mouth of Yellow river	0	90	5,384	1,992	4,991	2,260	5,662
Above mouth of Eau Claire river	23	113	5,760	2,131	5,999	2,418	5,340
Mouth of Eau Claire river	0	113	6,659	2,464	6,152	2,795	6,979
Above mouth of Menomonee river	29	142	7,004	2,591	6,493	2,939	7,366
Mouth of Menomonee river	0	142	8,961	3,316	8,307	3,762	9,424
Mouth of Chippewa river	23	165	9,573	3,542	8,874	4,018	10,068

Table of tributaries of the Chippewa.

River.	Length (map measurement).	Drainage area.	DISCHARGE PER SECOND.		THEORETICAL POWER UNDER 10 FEET HEAD.	
			Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Sq. miles.*	*Cu. feet.*	*Cu. feet.*	*H. P.*	*H. P.*
West branch of the Chippewa	35	480	178	445	202	505
East branch of the Chippewa	60	278	103	258	117	293
Courte Oreille	20	176	65	163	74	184
Flambeau	155	1,983	734	1,838	837	2,085
Jump	65	721	267	678	303	769
Yellow	65	458	169	415	191	471
Eau Claire	65	899	333	833	378	945
Menomonee	95	1,957	724	1,814	821	2,058

Reservoir system and logging-dams.—Surveys have been made by the United States engineers for reservoir sites, and eleven have been selected upon the headwaters and one on the main stream at Paint creek, 4 miles below the mouth of Yellow river. Their total cost will be about $355,000, and it is estimated that by means of them 2,800 cubic feet per second can be added to the flow of the river for 90 days during the summer and fall. This would raise the ordinary low-water discharge of summer from about 3,500 to 6,300 cubic feet per second.

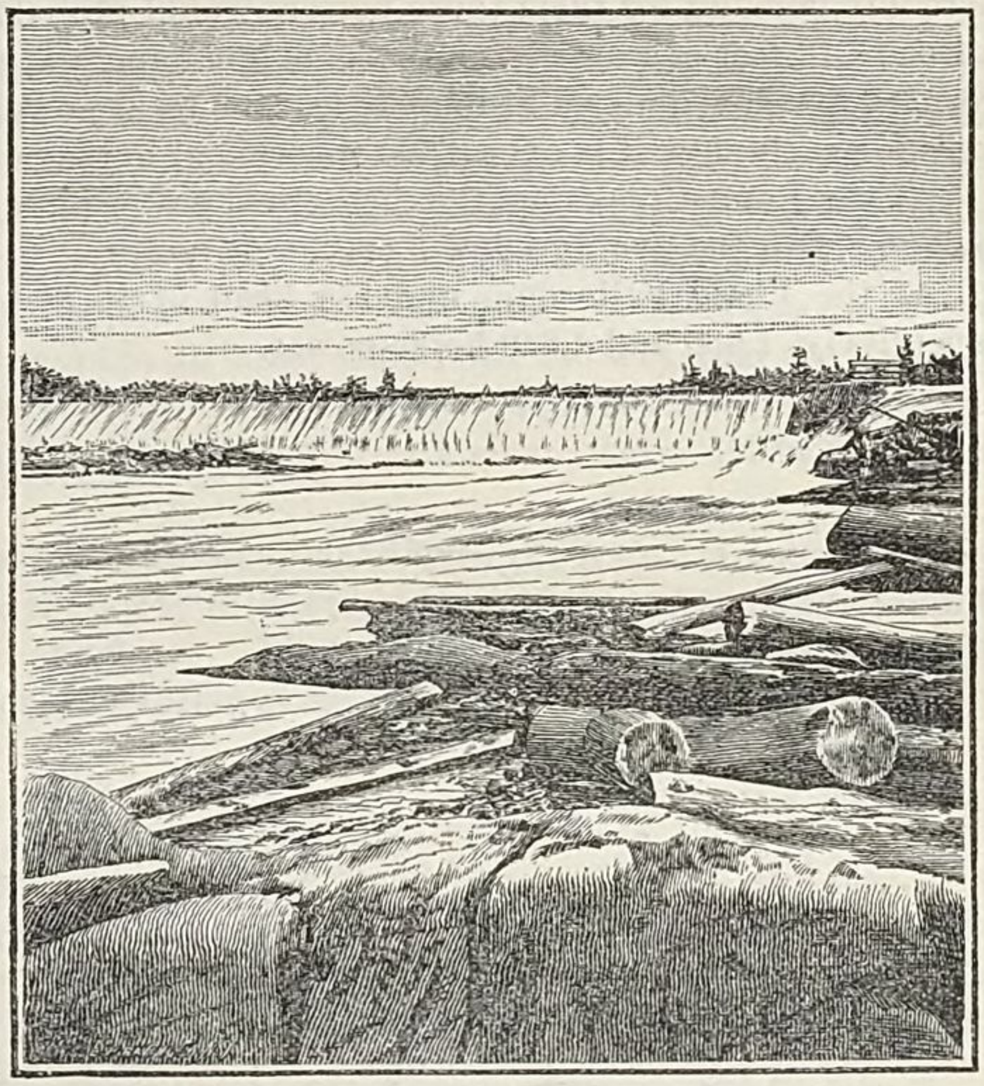
There are many dams upon the Chippewa and its branches for logging purposes, the same as in the case of the Saint Croix, but there are some upon the lower portion of the river much larger than any to be found on the latter stream. The three principal dams are the Dells dam, near Eau Claire, the Paint Creek dam, about 2 miles above Chippewa Falls, and the Little Falls dam, on the main stream some 4 miles below the mouth of the Jump river. There is also a dam at Chippewa Falls, giving a water-power at that place.

The Dells dam is the first one above the mouth of the river. The foundation is a fairly hard quality of sandstone. The construction is of square-timber cribs built up in crib-work. The dam is about 600 feet long and 19 feet high, 3 feet wide at the top, and with a base of about 8 feet. The slope on the upper side is about 3 to 1, and on the lower side 1 to 1. Both faces are planked over. The dam floods a large area, expanding the river to the dimensions of a lake, and when seen in the early summer of 1881 this was covered with logs as close as they could float for at least a mile in length and one-third or one-half a mile in width. The lower timbers of the crib-work are bolted to the rock by means of drift-bolts driven into holes which were previously filled with pine pins (the same method as was used in the dams at Minneapolis), and the different courses of the cribs are bolted to each other. At the foot of the lower face sleepers are bolted to the lower courses of timber and project down stream 20 feet. On them is an 8-inch covering of squared timbers to protect the bed from the plunge of the water. On the left bank are the sluice- and raft-slides, and on the right is a small flume leading to Half-Moon lake. Splash-boards are placed along the crest when necessary.

This dam was built by Mr. H. H. Douglass, agent of the Minneapolis Mill Company, and in this manner: During low water a coffer-dam was built out from the left bank and the sluice constructed, then another coffer-dam, and the dam built out toward the right bank; finally a coffer-dam was constructed from the right bank, and all the flow of the river turned through the newly-constructed sluice, and the dam built out from the right bank to meet the finished portion.

The Paint Creek dam is on the granite bed of the river, and, according to the United States engineers' report, is 526 feet long, with a crest 10.5 feet above low water. There is a rolling-dam 360 feet long, and in the center a rollway for logs about 100 feet long. There is also a lumber-slide 23 feet wide. The slope of the rear face is 1½ to 1, and of the front face 1 to 1.

The Little Falls dam is 625 feet long, with 267 feet width of sluice-way, and the height of the sluice-way above the flooring is 21 feet.



Point Creek dam, Chippewa river, Wisconsin.

The dams and the resulting reservoirs, controlled by the lumbermen, exert a very noticeable effect upon the flow of the river. The water is stored up till required, and then the gates are raised and the logs are sent down upon a flush of water. This causes an element of uncertainty in the flow, especially in the upper portion of the river, which would cause difficulty at times if manufactories were erected using the full flow; but nothing of that kind exists now, and the decline of the lumber interests will probably keep pace with the advance of manufacturing. If the existing reservoirs were managed solely with a view to steadying the flow of the river they would exert an important effect.

RAPIDS ON THE MAIN STREAM.

As before stated, little can be ascertained regarding the falls except from the reports of surveys by the United States engineers at the sources. Boats can ascend the river to Eau Claire, and there is no rapid in the stream below the Dells dam. "Below the mouth of the Eau Claire the maximum slope is 2.3 feet per mile, but only for a short distance, the mean slope being 1.64 foot per mile." In its natural state there were two rapids in the river between Eau Claire and Chippewa falls—one 1.25 mile above the Eau Claire, where the Dells dam is now situated, called the Lower Dalles, with 10.5 feet of fall in a little over 2 miles; the other about 4 miles below Chippewa falls, called the Upper Dalles, with 9 feet of fall in about 10,000 feet.

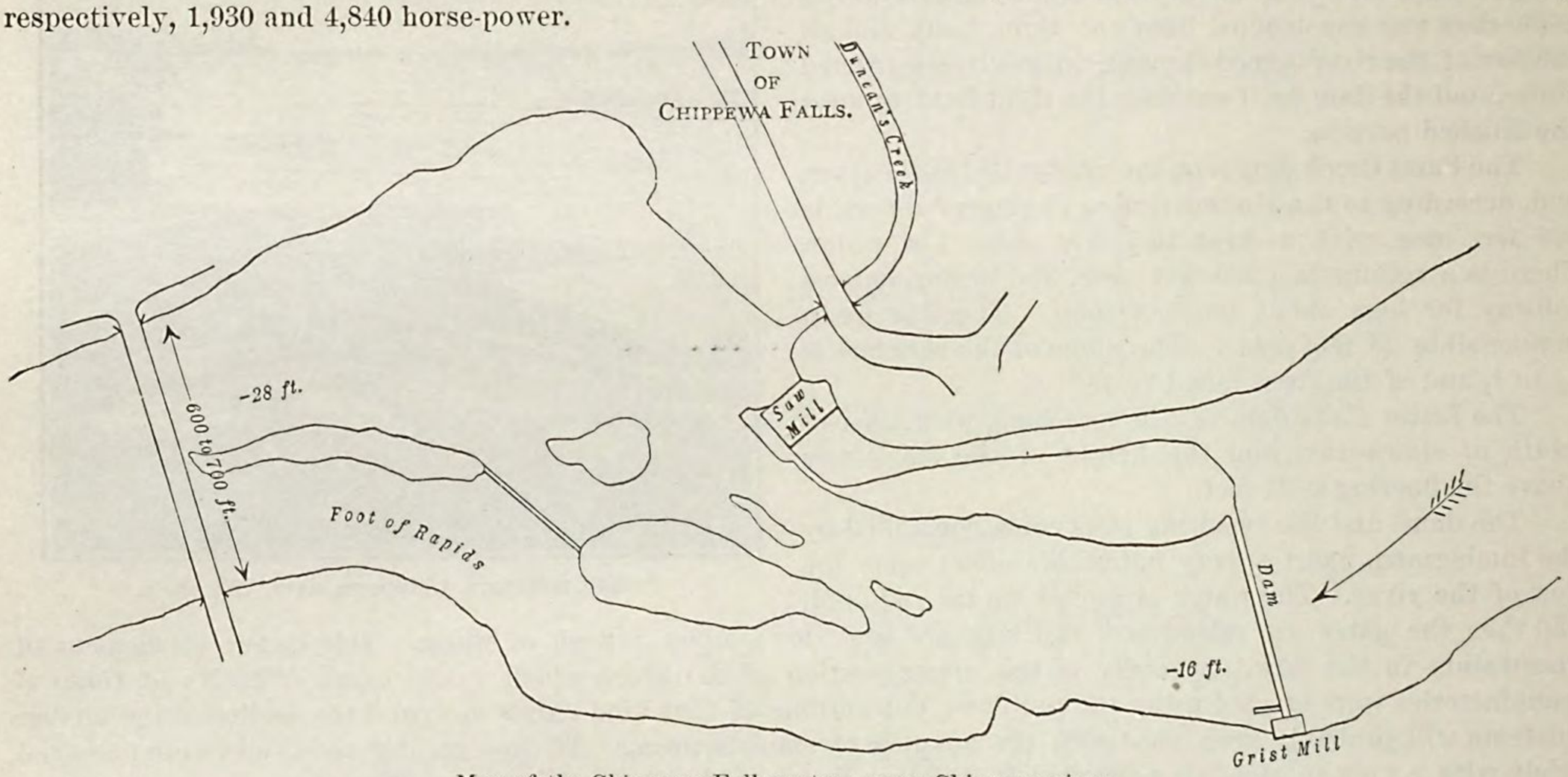
The next rapid is Chippewa falls, yet to be described. From Chippewa falls there are rapids or swift water distributed all along the river to the sources, and those familiar with the stream claim that the character of the bed and banks is such as to make it practicable to develop powers at a great many points. In the United States engineers' reports the statement is made that, from the mouth of Courte Oreille river down to the Big bend, the Chippewa has a swift current throughout the entire distance and no rapids of any consequence. The fact of the building of the Paint Creek and Little Falls dams indicates the existence of available power between Chippewa falls and the junction of the two branches of the river. On these branches the surveys of the United States engineers prove the presence of many rapids. Thus there is a fall of 43 feet in the last 2.75 miles of the East branch. At the head of these rapids is Little Chief lake, and from this lake up to Bear lake, a distance of about 15 miles, there is a rise in the river of 110 feet. The heaviest rapids in this distance are Cedar rapids, 54 feet in about 3 miles, and

Snaptail rapids, with a fall of 45 feet in about 1.5 mile. From Bear lake up to Chippewa crossing, where the Wisconsin Central railroad crosses the river, a distance of some 15 or 20 miles, the total rise is about 76 feet. The river at the crossing is near the divide which separates it from the Bad river, flowing into lake Superior, and is a small stream, from 25 to 40 feet wide. The West branch does not appear to be so rapid. From the junction to the mouth of Little Chief river the rise is only 7 feet in 5 or 6 miles. Above that is a succession of rapids and still reaches to Partridge Cross lake, the rise being 97 feet in 20 or 25 miles. Above the lake the river is sluggish to its source. This smaller slope of the West than of the East branch might be assumed from a knowledge of the general slope of the country, as the Lake Superior divide falls in passing from east to west. Assuming 0.37 cubic foot per second per square mile as the ordinary low flow, the theoretical power of the West branch under a head of 10 feet at the mouth is 200 horse-power, and of the East branch 120 horse-power. These are probably low estimates.

Power at the dams.—There are many powers immediately available at the dams which already exist, and were there any demand for them these powers would probably soon be used. The Dells dam is directly on the line of railroad; 16 feet of water is available at the dam, and there are rapids for several hundred feet below. With the ordinary low flow under a head of 16 feet the total power is not less than 3,800 theoretical horse-power, and with the average yearly flow it is over 8,500 theoretical horse-power.

At the Paint Creek dam the theoretical power under a head of 10 feet is 2,260 horse-power with the ordinary low flow, and with the average flow 5,660 horse-power.

At the Little Falls dam under a head of 10 feet the theoretical power with the two conditions of flow is, respectively, 1,930 and 4,840 horse-power.



Map of the Chippewa Falls water-power, Chippewa river.

CHIPPEWA FALLS—THE ONLY UTILIZED POWER.

It is said that there was at one time a mill at Chippewa City, a few miles above the mouth of Yellow river, but now the only power in use on the main river is at Chippewa falls. There the river, when in its natural state, rushed down over great masses of solid granite. Now a dam is built across the main channel from the left bank to a rocky island, then runs down that and across the smaller channel to the right bank. The town of Chippewa Falls is situated on the right or west bank of the river, extending down stream from the dam. Built along the face of the dam over the small channel is a large saw-mill, and on the eastern shore, at the extremity of the main dam, is a flouring-mill. These are the only establishments using the power.

There was formerly a bridge crossing the river just below the island, but it was carried away during the unusually high water of June, 1880. The total fall from above the dam down to the lower bridge is about 28 feet, of which 16 feet is at the dam, and when in a high stage, the river rushes down white with foam over the rocks below the dam. On the west side the shore takes a wide sweep inland, just below the saw-mill, forming a quiet bay, and there Duncan creek enters the river. The saw-mill is one of the largest in Wisconsin; there are three or four gang-saws and as many "rotaries", besides the necessary machinery for trimming the lumber and working the waste into laths and shingles. As many as 1,700 logs are sawed per day, giving about 450,000 feet (board measure) of lumber. At the foot of the building men are busy making rafts out of the lumber, which is floated out into the river, and so down-stream. The space in the west channel above the mill is used as a pocket in which the logs are held ready for use. There are in all seventeen wheels in use in the saw-mill, but the machinist does not

rank any of them as first-class wheels, some being the old-fashioned flutter-wheels; and the result is that much power is wasted. According to the census returns the total power used by the mill is 1,084 horse-power. The wheels work under a head of 14 feet, taking 7,440 "inches" of water. Considerable head of water is lost in the distance from the main pond down to the mill, as there is a strong current in the pocket, even when the water is falling over the crest of the dam near the mill, showing that it is not due to the wheels drawing off the water.

There is no difficulty experienced from backwater when Duncan creek is high, and ordinary high water on the river does not stop the wheels. The grist-mill at the end of the main dam uses 124 horse-power under a head of 12 feet. Hence there is only 1,208 horse-power in use where at least 3,600 horse-power is available with the ordinary low flow under a head of 16 feet. This bears out the statement made by the machinist of the saw-mill, that at a low stage of the river fully double the flow was available that was in use.

Utilized power at Chippewa falls.—The total fall from the quiet water above the dam down to the foot of the rapids is stated to be 28 feet. This would give, with the ordinary low flow, 6,300 theoretical horse-power, and with the average yearly flow, 15,800 theoretical horse-power. The power actually in use is only 1,208 horse-power, but there is great waste in the method of taking it. Even allowing an efficiency of only 50 per cent. for the wheels, there must be at least 3,800 theoretical horse-power unemployed at Chippewa falls during ordinary low water. This cannot be very well used directly at the dam. On account of Duncan's creek entering the river, the relation of the streets of the town, and the location of the saw-mills, there is not a very good opportunity for development on the right bank of the river, but on the left bank the situation appears much more favorable, so far as can be judged from a brief inspection. The true bank of the river is at an average distance of perhaps 100 feet from the water in ordinary stages, and extends down-stream nearly on the level of the top of the dam. Between this bank and the river is a mass of rock, while the bank itself is earth covering the solid rock, down which a canal could be extended, supplying mills.

Possibly in excavating the canal it would be found necessary to do some blasting in the rock. A short distance below the dam is the abutment of the bridge which was carried away in the freshet of 1880, and if this is rebuilt, some changes would be necessary in case of the construction of a canal. The railroad runs along the east bank of the river, and side-tracks could readily be carried down to manufactories along the canal.

TRIBUTARIES OF THE CHIPPEWA RIVER.

The Flambeau and the Menomonee are the largest two, the first draining 1,983 and the second 1,957 square miles. The next stream in extent of drainage area is the Eau Claire, with 899 square miles; then the Jump river, with 721 square miles; the Yellow river, with 458 square miles, etc. The West and East branches, draining respectively 480 and 278 square miles, have been already alluded to.

Like the two branches just mentioned, the tributaries have many rapids affording available sites, but there are few of them improved.

On the upper waters of the north fork of the Flambeau, from the crossing of the Wisconsin Central railroad up to Rest lake, a distance of about 75 miles, there is a rise of 126 feet, and 85 feet of this occurs, in the first 21 miles. There are several falls upon the Flambeau and its tributaries which have been considered of sufficient importance by the lumbermen to receive names.

The Jump river, as its name indicates, is a rapid stream, and so are the Yellow river and a number of smaller tributaries entering the Chippewa in that region. Their valleys are, however, mostly narrow, subject to rapid drainage, and the streams are not so steady in their flow as several of the other tributaries.

The Courte Oreille river drains an area of only 176 square miles, but its source is in a large lake of the same name, some 6 miles long by about 1 mile wide, and Grindstone lake, of nearly the same area, is tributary to it. These tend to regulate its flow. The river is sluggish in its first 3 miles, but in the remaining 12 or 15 miles to the Chippewa it is a succession of rapids and still water, including Courte Oreille falls. A reservoir site has been surveyed at the foot of the lake.

At Cadott, upon the Yellow river, some 10 or 12 miles from its mouth, are a flouring-mill using 20 horse-power under a head of 14 feet, a saw-mill, and a hub- and spoke-factory.

EAU CLAIRE RIVER.

The Menomonee and the Eau Claire rivers are controlled by the lumbermen. A lumber company, with the head office at Eau Claire, has a number of dams on the Eau Claire river, some of them close to each other, and this company has to a slight extent used the water-power under its control. The lowest dam is situated in the town of Eau Claire, and there the company has a flouring-mill on the left bank, using about 150 horse-power under a head of 8 feet. There are four runs of stones, and two sets of double rollers. On the right bank is a saw-mill using steam-power, but there is associated with it a small machine-shop run by water-power, and under the control of the company. The only other power used on the river is at one of the company's dams above, where it has a saw-mill.

with a capacity for using 500 horse-power under a head of 12 feet. This is stated to be the capacity of the stream in low water. Assuming an ordinary low flow of 0.37 cubic foot per second per square mile, the theoretical horse-power at the mouth would be about 450 horse-power under a head of 12 feet.

MENOMONEE RIVER.

The Menomonee, called the Red Cedar on some of the maps, but now generally known by its old Indian name, Menomonee, has some twenty-five logging dams upon it. It rises in several lakes a few miles south of Lac Courte Oreille and the Namecagon river of the Saint Croix basin, and has already been described as draining nearly all the southwestern portion of the Chippewa basin.

The use of the great number of flushing-dams on the river renders its flow uncertain, and it is considered that when the lumber interests have declined the river will be much more desirable for water-power and will be more extensively used than at present. The river verges upon the prairie region, in its lowest part at least, and hence there is more prospect of the early development of its water-power than in the case of the Flambeau.

According to the census returns there are three flouring-mills on the Menomonee, one using 250 horse-power under a head of 11 feet, another 40 horse-power under a head of 10 feet, and the third 20 horse-power under a head of 16 feet. There are also three saw-mills using 1,000, 400, and 65 horse-power under heads of 11, 18, and 12 feet, respectively. There is also a foundery and machine-shop using 36 horse-power under a head of 11 feet. The large saw-mill and flouring-mill are situated at the town of Menomonee, which is 2 miles south of the railroad crossing, and some 15 or 20 miles above the mouth of the river.

There are many small streams in the southern part of the Chippewa basin which are already utilized by mills of various kinds, as, for example, the Aux Galle. Duncan's creek, which enters at Chippewa Falls, is 30 or 40 feet wide, and is fed by springs which make it very steady in flow, except when swollen by surface water. The machinist of the saw-mill at Chippewa Falls said that with a head of 12 feet it would furnish 35 horse-power at the lowest stage, and he would prefer it to a steam-engine of equal power. It is probable that there are many such spring brooks feeding the Chippewa which can furnish moderate powers of great constancy when required.

The census returns credit Duncan's creek with three flouring-mills of 132, 100, and 60 horse-power, under heads of 20, 10, and 12 feet, respectively; one saw-mill using 50 horse-power under a head of 12 feet; and two sash- and door-factories, each using 24 horse-power under a head of 9 and 10 feet, respectively.

BLACK RIVER.

The Black river is much smaller than those streams that we have just been considering, but from its position and general features may be properly classed with them. Its drainage basin of 2,272 square miles is long and narrow, wedged in between the Wisconsin on the east and the Chippewa on the west. In one place where the Eau Claire branch of the Chippewa, and the Poplar river, a stream of the Wisconsin basin, approach each other, the basin of the Black is scarcely more than 3 miles in width; it widens out above, however, to some 10 miles or more across. The general direction of the river is southwest, with a gradual bend from south to west, and it enters the Mississippi about 680 miles from its source, after a course of 128 miles. The mouth is about 10 miles above the city of La Crosse, Wisconsin.

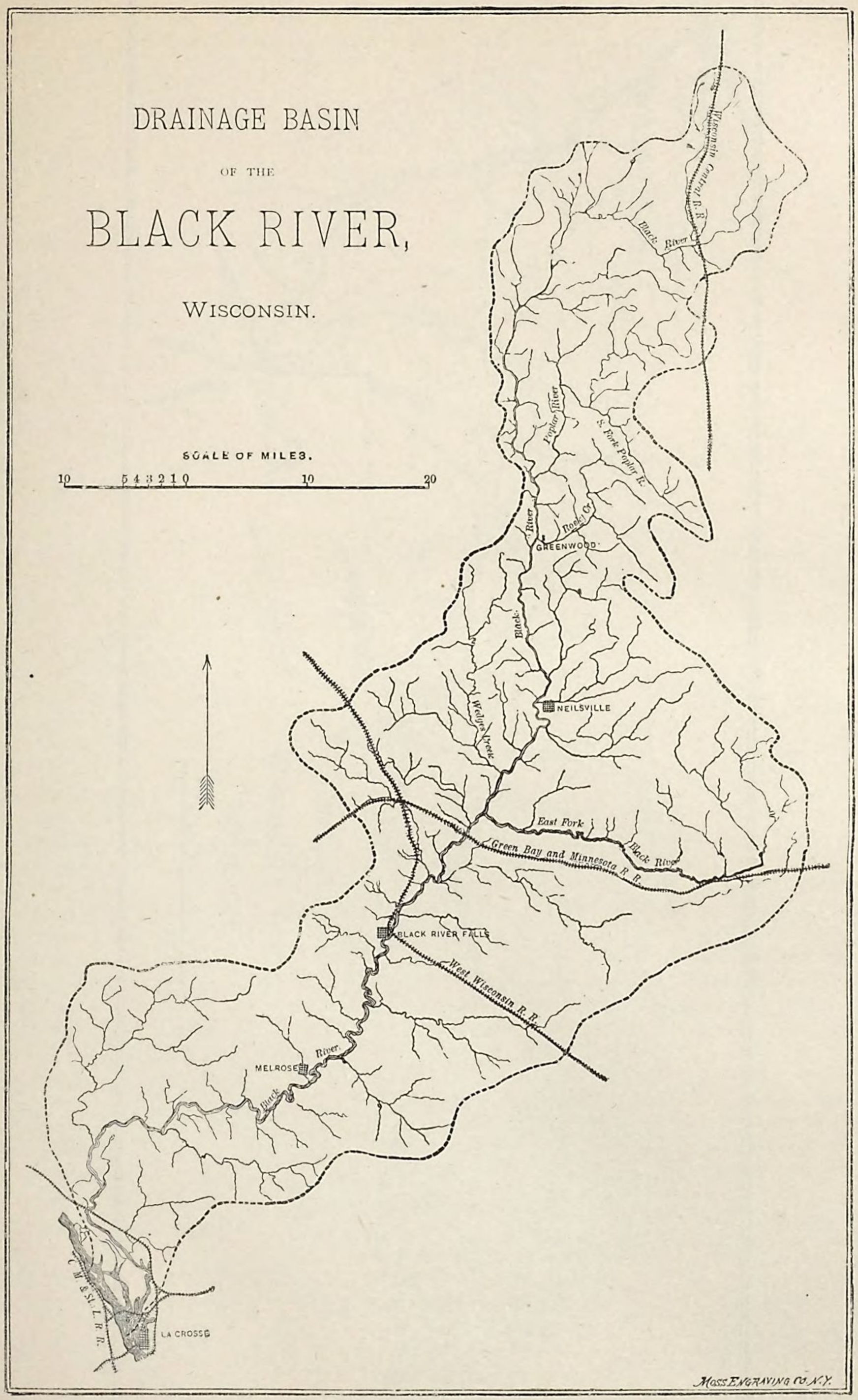
The drainage-basin partakes, of course, of the same general character possessed by the basins on each side of it. The southern portion of the pine region crosses the basin between 60 and 80 miles from the mouth of the river, and all the upper half is pretty much covered with timber. Along the lower portion of the river the country has more of the open nature characteristic of the lower part of the Chippewa basin. The soil there is heavier, containing more clay, but in the pine region there are sand ridges. These are sometimes replaced by a heavier clay soil, as is the case in the neighborhood of Neillsville, 85 miles from the mouth of the river. The rich soil there makes excellent farming land, grows fine hardwood timber, and the transition to the sand ridges lying east is very apparent. The surface of the basin is either level or rolling.

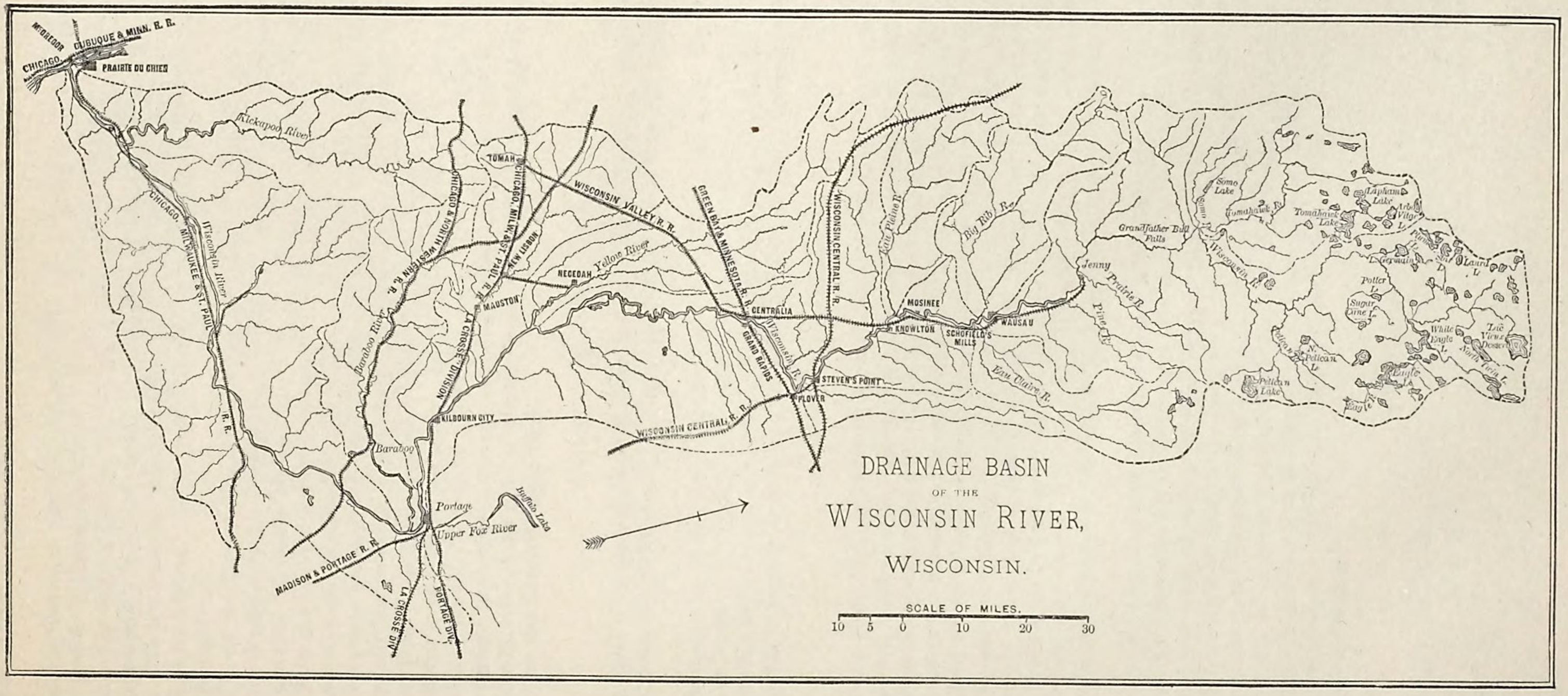
Lumbering has been the great business along the river, and for 17 years the average yearly cut has been 140,000,000 board feet. All the fine pine now standing is on the upper waters, and it is considered that it will not last much over five years longer, but there is a vast amount of inferior timber yet to be taken. Poplar wood occurs in large quantities.

All the country about the lower portion of the river is pretty well settled and under cultivation. The principal towns are Black River Falls, about 60 miles from the mouth, and Neillsville, which is a short distance back from the stream, and about 85 miles above its mouth.

The two railroads crossing the basin are the Chicago, Saint Paul and Minneapolis, which crosses the Chippewa at Eau Claire, and the Black river at Black River Falls; and the Green Bay and Minnesota railroad, which crosses the Black river about 11 miles above Black River Falls. There is a branch from this latter road running to Neillsville.

There are a few lakes at the upper waters, but the basin is not very well supplied with these natural reservoirs, and if it were not wooded and largely covered with a porous soil its streams would be very unsteady, especially


DRAINAGE BASIN
OF THE
BLACK RIVER,
WISCONSIN.
SCALE OF MILES.
10 5 4 3 2 1 0 10 20
Wisconsin Central R. R.
Black River
Poplar River
S. Fork Poplar R.
Rock Cr.
GREENWOOD
Black River
Wedges Creek
NEILSVILLE
East Fork
Black River
Green Bay and Minnesota R. R.
BLACK RIVER FALLS
West Wisconsin R. R.
MELROSE
Black River
C. M. & St. L. R. R.
LA CROSSE
MOSS ENGRAVING CO. N.Y.



DRAINAGE BASIN
OF THE
WISCONSIN RIVER,
WISCONSIN.

SCALE OF MILES.
10 5 0 10 20 30

on account of its long, narrow form. As it is, the Black river has the reputation of rising and falling rather rapidly, but it maintains its flow fairly during low water.

There are a number of logging-dams on the river, and if these were controlled in the interests of water-power they would aid very materially in regulating the flow. This can probably be done in the future if the demand for power be sufficient. The low water, as with the other rivers of the region, is usually for about a month, in July and August and during severe winters. At an average section of the bed the ordinary rise is about 6 feet, and a rise of 18 feet is a very unusual one.

Between Black River Falls and Neillsville the channel is from 150 to 250 or 300 feet wide during a fair stage of water. The source is stated in the *Geological Report of Wisconsin* to be between 1,300 and 1,400 feet above the sea, and hence the total fall of the river must be about 750 feet, or over 4.5 feet per mile. The slope is less below Black River Falls than above, and at that place is the last appearance of the hard metamorphic rock in the river. Below it flows through the sandstone region, while above it is described as being "constantly broken by chutes and rapids over gneiss and granite". Owing to the form of the basin the flow must diminish rapidly toward the source, and hence also the power for a given fall. At the mouth the area tributary to the river is 2,272 square miles; at Black River Falls it is 1,569 square miles, and at Neillsville, only 25 miles above, it is only 729 square miles.

There are no tributaries of special importance, as might be inferred from the shape of the basin. The largest is the East fork, which enters the river about half way between Neillsville and Black River Falls, and drains 305 square miles in the eastern projection of the basin; all the other side streams fall far short of this in extent of drainage area. The tributaries of the Black river are characterized by many rapids and moderate falls, and there are some small flouring- and saw-mills upon them.

POWERS ON THE MAIN STREAM.

Some years ago there were several saw-mills run by the power of the Black river, but there was a lack of capital to construct booms, etc., sufficient to withstand the freshets on the river, and the mills have been nearly all abandoned.

There are only three points on the river at which power is utilized at present. These are Black River falls, Greenwood (some 15 miles above Neillsville), and a point 4 miles above Greenwood. At Greenwood and the privilege above there are, according to the census returns, a grist-mill using 85 horse-power under a head of 17 feet, a saw-mill using 48 horse-power under a head of 17 feet, and a small saw-mill using 15 horse-power under a head of 12 feet.

BLACK RIVER FALLS.

At Black River falls there are very heavy rapids for a short distance over hard granite rock. At the right hand of the main channel, which is about 150 feet wide, is a small island, and at its head is a low dam, extending across the main channel, and turning the water to the manufactories situated on the island and right hand shore. These are a flouring-mill of 150 horse-power, a saw-mill of 150 horse-power, and a sash and door factory of 75 horse-power, all running under a head of 10 feet. These are all owned by one person, who has the right to 2,500 "inches" of water at all seasons, and 5,000 "inches" when the river is at a stage of 1 foot above low water. The remaining power belongs to another owner, but is entirely unemployed. There is room for utilizing the full power of the stream, but the head cannot be increased by raising the dam, as it would flood up on streams where there are mills. There is, however, considerable fall unimproved below the dam. From the angles in the rock, and its compact, hard nature, it seems probable that valuable granite quarries could be opened at Black River falls, very near the railroad.

Unemployed power.—So far as could be ascertained, there is no practically available power found on the river above the mouth, until within a mile of Black River falls, where 9 feet of fall could be obtained.

The next place is 2 miles above Black River falls, where 10, 15, or even 20 feet of head is available, according to the height of dam built. From there up to the Dells dam, 14 or 15 miles above, there is a heavy fall, and available power at a great many localities. The Dells dam is used for logging purposes.

From the dam up to 3 miles below Neillsville, a distance of about 6 miles, there is no available power, but above that, up to the source, there is a rapid slope in the stream and much available power.

At the rapids in the Black river the bed and banks are usually of granite rock, and the situations are many and excellent for utilizing the power.

WISCONSIN RIVER.

The Wisconsin river has the largest drainage area of all the rivers of the state of Wisconsin; and in the sense that the Minnesota is *the* river of Minnesota, so can this river claim the title of *the* river of Wisconsin. The inhabitants of the region frequently dub it "the Old Wisconse".

The river rises in Lac Vieux Desert, a sheet of water some 10 square miles in extent, lying directly on the line separating the upper peninsula of Michigan from Wisconsin, and after a course of about 400 miles, enters the

Mississippi just below Prairie du Chien, and 40 miles above the southern boundary of the state. The general course of the river is nearly directly south for about 300 miles, to Portage City, and then it turns sharply, and flows west and southwest for the remainder of the distance to its mouth.

Description of the basin.—The drainage basin of 12,280 square miles has an average width of about 50 miles, and is 225 miles long. The river flows, for the most part, in the eastern half of the basin, and below the bend at Portage it follows within about 10 miles of its southern edge. At Portage the line of water-shed, if it can be said to exist there at all, passes within a mile east of the river, a peculiarity to be referred to farther on.

The long and narrow basin of this river extends in a south-southwest direction nearly across the state, and illustrates, more fully than either the Chippewa or Saint Croix basins, the main topographical features already discussed when treating of those rivers. There is the same wooded (pine) region, extending from Michigan down to within about 40 miles by river of Portage city; below that the pine disappears, and a semi-prairie region gradually takes the place of the woods, the same as in the Chippewa and Saint Croix basins. The country is undulating, and in places decided ridges break the surface. In the southern part of the basin the Baraboo ranges of quartzite pass east and west, from 400 to 700 feet above the surrounding country, and form a striking feature of the scenery. The bluffs along the lower river, especially on the south side, rise several hundred feet, forming prominent ramparts to the valley. Back from these the country is level or undulating.

In the northern portion of the basin are many lakes and tamarack swamps, like those which characterize the headwaters of the Chippewa, being in fact but a continuation of the same system; and all the way down to Portage there is more or less swamp land between the ridges. The soil in the lower portion of the basin is heavier, containing more clay than in the pine regions, where a light, rich loam supports the heaviest growth of pine; and where in some places sand is a chief constituent of the ridges.

The lower half of the basin is pretty well settled, and the advance posts are rapidly passing up into the region to the north. Lumbering has been the chief business on the river, but the center of the lumber interests is moving up-stream toward the headwaters, and, as with the other rivers, the good pine is fast disappearing. The principal towns on the river above Portage are Grand Rapids, about 90 miles above, then Stevens Point, 20 miles farther up, then Wausau, 45 miles above Stevens Point, and finally Jenny, about 20 miles above Wausau. All these towns have saw-mills, and owe their existence to the lumber trade. The lower ones are gradually drawing other branches of industry within their limits, and are becoming centers of trade for the surrounding population; but those farther up the river, as Jenny and Wausau, have yet to pass from the first stage in their history.

Numerous railroads cross the lower half of the basin, belonging chiefly to the Chicago, Milwaukee and Saint Paul, and the Chicago and Northwestern companies. The Wisconsin Central has its line to Saint Paul, crossing the river at Stevens Point, and the Green Bay and Minnesota railroad crosses the river at Grand Rapids, striking the Mississippi at La Crosse; and, finally, there is the Wisconsin Valley railroad, which, starting from the Chicago, Milwaukee and Saint Paul at Tomah, runs north, crossing the river at Knowlton, about 20 miles above Stevens Point, and then running along its east side to Jenny, the present terminus of the line. About 6 miles above Knowlton it passes by Mosinee, a lumbering town. These railroads in the lower part of the pine regions are now used very extensively for shipping lumber, and the statement was made that probably not more than one raft passes down to Portage now, for twenty that used to pass down the river in former years. This decrease is not due to a decline in the lumber trade, but to the change in the method of transfer.

Geology of the river.—Like all the large rivers of the state, the Wisconsin heads in the high drift region underlaid by the primitive Archæan base of the continent, and flows south over successive strata of sedimentary rock to the mouth. This has led to its division into two sections. The upper one is the Archæan region, in which in many places the bed is worn through the drift and down to the hard metamorphic rock, which, presenting a barrier to further erosion, causes numerous rapids. This section ends at Point Basse, about 8 miles below Grand Rapids, where the last outcrop of granite is found in the bed of the stream. Then begins the second section, in which the river has found a more yielding material into which to cut its bed. This is largely the Old Potsdam sandstone, and the disintegration of this has made the bed of the river one succession of shifting sand-bars, almost without interruption, to its mouth. Where it is near the surface in the surrounding country, the soil is very light, and even sterile in places.

For a distance of 7.5 miles, ending at Kilbourne City, which is about 21 miles above Portage, the river flows through what are known as the Dalles of the Wisconsin. Like the Dalles of the Saint Croix, they consist of a narrow gorge through which the river passes, but instead of rocky cliffs of trap, the walls have been carved out of the Potsdam sandstones 50 or 100 feet high, evidently by the river itself. Above the Dalles the river is over a third of a mile wide, but it immediately narrows down to 200 feet, which is its average width through them. In one place it is only 50 or 60 feet wide. The softer character of some of the sandstone layers has caused unequal erosion, and some very singular and picturesque forms have been given to the cliffs, making the Dalles a great resort for tourists and pleasure parties.

From a short distance below Portage, down to the mouth, the river valley is characterized by bluffs, which gradually increase in height, until near the foot of the river they have the full height of those bordering the Mississippi trough. They often rise on the south side 300 or 350 feet above the valley, nearly vertical. They are formed by the projecting edge of the Lower Magnesian limestone, which, acting as a high barrier, has forced the river to flow westward until it found a passage in the deep trough of the Mississippi.

Mention has been made of the Baraboo ranges, which consist of two ridges of quartzite extending east and west in the section of country west of Portage. They are from 4 to 6 miles apart, about 25 miles long, and unite in an abrupt headland in the bend of the Wisconsin opposite Portage, where they end. Between them is a depressed area. It is apparent that the bend of the river to the eastward and then west, is due to the effort to find a passage around this rock barrier. Above Portage the river has been found fully large enough to account for its valley, while below it is much like the Minnesota river, lost to a certain extent in the big trough through which it flows. The reasons for this peculiarity, as obtained from the *Geological Report of Wisconsin* have been briefly given in treating of the Fox River basin, and are these:

Change in the drainage system.—The line of water-shed on the east side of the river at Portage can scarcely be said to exist; a low sandy plain not more than 2 miles wide, and only elevated a few feet above the river, is all that separates it from the upper Fox, which flows northeast, uniting with the Wolf river, and then flowing north to lake Michigan.

At places this plain is highest nearest the Wisconsin, and in high water the overflow of the Wisconsin causes freshets on the upper Fox. It is evident that such an uncertain divide as this cannot have formed one of the original permanent features of the drainage of the region, but as the disposition of the surface soil is due to glacial action, modified, it is true, by subsequent erosion and transportation, this may be fairly attributed to such a cause. The rampart of limestone which compels the lower Wisconsin to flow west, does not stop south of Portage, but continues east and north, although less prominent, forming an eastern barrier to the flow of the Wolf river. The course of the upper Fox to lake Winnebago is sluggish, consisting largely of marsh and lake-like expansions. On account of the depression of the divide at Portage, the continuation of the southern barrier northeast, the small slope of the upper Fox, the large trough of the Wisconsin below Portage, which it is unable to occupy, while above the river is more nearly in proportion to its channel of drainage, and finally the evidently modern outlet for the Wolf and the upper Fox through the lower Fox river—the conclusion is reasonable, if not inevitable, that at one time the lake Winnebago system drained southwest into the Mississippi, and the Wolf river was the true continuation of the Wisconsin above Portage, while the present upper Wisconsin was merely a tributary of the main stream. During the changes incident to the deposition of the drift, the channel was choked up, and partly owing to this, perhaps also due to a change in elevation, as suggested by General G. K. Warren, the drainage was directed to lake Michigan.

The records left on the face of the country afford an interesting insight into the past history of that tributary stream which now forms the upper portion of the Wisconsin river. It has been mentioned that it is deflected to the east by the Baraboo range, passing around the eastern outpost at Portage. There is a deep gorge cutting south through the ranges, entering the Wisconsin valley near Sauk City, some 25 miles below Portage. This has been largely filled with drift, and two immense heaps dam up the gorge, forming Devil's lake, with its wild, romantic scenery. It is thought that this gorge was at one time the channel of the river, but being choked with the material carried down by the glaciers, the river was deflected and compelled to seek a new channel around the ridge.

Table of distances, flow, etc., of the Wisconsin.

Station.	Distance from preceding station. (a)	Distance from source.	Drainage area above station.	Flow per second past station.		Theoretical horse-power under 10 feet head.	
				Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Miles.*	*Sq. miles.*	*Cu. feet.*	*Cu. feet.*	*H. P.*	*H. P.*
Above mouth of Pelican river	60	60	940	367	872	416	989
Mouth of Pelican river	0	60	1,202	469	1,115	532	1,265
Mouth of Tomahawk river	25	85	2,111	823	1,959	934	2,222
Mouth of Prairie river	28	113	2,877	1,122	2,670	1,273	3,029
Above mouth of Rib river	23	136	3,192	1,245	2,962	1,412	3,360
Mouth of Rib river	0	136	3,690	1,439	3,324	1,633	3,771
Mouth of Eau Claire river	2	138	4,114	1,604	3,820	1,820	4,334
Above mouth of Eau Pleine river	20	158	4,268	1,664	3,961	1,888	4,495
Mouth of Eau Pleine river	0	158	4,645	1,811	4,311	2,055	4,881
Mouth of Little Eau Pleine river	8	166	5,005	1,952	4,645	2,215	5,270
Mouth of Plover river	18	184	5,300	2,067	4,918	2,345	5,580
Above mouth of Yellow river	64	248	6,448	2,513	5,984	2,851	6,789
Mouth of Yellow river	0	248	7,394	2,884	6,862	3,262	7,785
Mouth of Lemonweir river	11	259	8,172	3,187	7,584	3,616	8,604
Mouth of Baraboo river	33	292	9,095	3,547	8,440	3,024	9,575
Above mouth of Kickapoo river	97	389	11,387	4,440	10,567	5,037	11,988
Mouth of Kickapoo river	0	389	12,159	4,742	11,284	5,381	12,702
Mouth of Wisconsin river	18	407	12,280	4,784	11,396	5,427	12,929

a Map measurement above Baraboo river.

Tributaries of the Wisconsin.

River.	Length (map measurement).	Drainage area.	Discharge per second.		Theoretical horse-power under 10 feet head.	
			Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Sq. M.*	*Cu. feet.*	*Cu. feet.*	*H. P.*	*H. P.*
Pelican river	25	262	102	243	115	276
Tomahawk river	50	714	278	664	315	753
Rib river	50	498	194	462	220	524
Eau Claire river	50	423	165	383	187	435
Eau Pleine river	50	377	147	350	167	397
Yellow river	70	946	369	878	419	996
Lemonweir river	50	588	229	546	260	619
Baraboo river	70	655	255	608	288	690
Kickapoo river	75	760	296	705	336	800

Hydrography.—Owing to the form of the basin and to the course which the river takes through it, there are no very large tributaries. The drainage basin is pretty well distributed among the different branches, and the drainage falls into the stream quite regularly in proportion to its length from north to south. The principal exception to this is in the case of the Yellow river, the largest tributary, which makes some 60 miles of southing before it reaches the Wisconsin. The principal branches from the source down are the Tomahawk, or Little Wisconsin of some maps, with 714 square miles drainage area; the Rib river, 498 square miles; the Eau Claire, and Eau Pleine, each draining less than the Rib river; the Yellow river, 946 square miles; the Baraboo, 655 square miles, and the Kickapoo, 760 square miles.

Flow.—The wooded character of all the upper portion of the basin, the swamps and lakes, and the porous nature of so much of the soil, all act, as in the case of the Saint Croix and the Chippewa, to maintain the flow of the river during dry and cold seasons, and make the Wisconsin one of the steadiest, if not the most uniform, in flow of all the large tributaries of the upper Mississippi. As nearly as can be ascertained from gaugings and from comparison, the average ordinary low flow is 0.39 cubic foot per second per square mile, an amount greater than in the case of the sources of the Mississippi; but it must be remembered that the rainfall per year averages about 35 inches.

In calculating the flow at various points for the accompanying tables, the average factors for the entire basin have been used throughout, although some of the tributaries undoubtedly have a more uniform flow than others. The river is considered a steady stream by those using its water-power. The ordinary rise at Jenny is about 6 feet above low water, and at Grand Rapids a rise of 8 or 10 feet above low water is considered very high.

Surveys have been made at the sources for reservoirs. The basin does not appear to afford so many available holding-grounds as those previously discussed, and it is not thought that any will be found on the main stream below the mouth of the Tomahawk. Above that there have been eight surveyed, which can be developed at a cost of about $200,000, and it is estimated that they would add a discharge of 2,300 cubic feet per second for ninety days during the summer to the low discharge of the river, which is about 5,000 cubic feet per second.

It is perhaps proper to mention in this connection the system of navigation from lake Michigan to the Mississippi by means of Green bay and the Fox river to Portage, and then down the Wisconsin to the Mississippi. This has been described in the report on the Fox river, and will not be dwelt upon now further than to state that practically it is of no use except for local trade on the lake Michigan side of the divide. The extremely unstable nature of the bed of the lower Wisconsin renders it a most difficult engineering feat to maintain a navigable channel, which has not yet been accomplished, and probably will not be enforced without great expense. It was proposed by General Warren to leave the river entirely and construct a canal along its valley to the Mississippi. On the lake Michigan side the character of the streams admits of the comparatively easy maintenance of a navigable course.

Fall of the main river.—Lac Vieux Desert is near the high divide separating the lake Superior drainage from that flowing south, and at an altitude of 1,532 feet above the sea. The mouth of the river is about 600 feet above sea-level, and hence in its course, estimated to be 407 miles, it falls 932 feet, an average of 2.29 feet per mile. The elevation of the river at Kilbourne City, at the foot of the Dalles, is 814 feet above the sea; hence, in the distance of 140 miles to the mouth, the total fall is 214 feet, or 1.53 foot per mile. Below Portage it is 1.5 foot per mile, as ascertained by General Warren's survey. Above Kilbourne City the total fall is 718 feet in a distance estimated to be 267 miles, or 2.69 feet per mile. Above Grand Rapids the total fall is, approximately, 530 feet in a distance of 200 miles, and the average slope is 2.65 feet per mile.

About 10 miles below Grand Rapids is Point Basse, which marks the southern limit of the Archæan section of the river, and in this distance are heavy rapids. It is evident, then, that the most rapid part of the river is in the

Archæan section, and here, with one exception, are the available water-powers. Above Wausau the slope is 2.45 feet per mile, but between Grand Rapids and Wausau it averages about 3.12 feet per mile; and it is in this distance of about 66 miles that the bulk of the available power is situated. Although there are numerous rapids available above Wausau, one very extensive one is yet to be mentioned.

The bed of the river is rock at the rapids, but at intermediate places it is largely made up of sand, gravel, and bowlders. The situations are fine for the development of water-powers, and the existing dams do not flood any considerable extent of land. These dams are the ordinary log constructions known as "spar-dams".

The amount of information obtained regarding the extent of the rapids of the Wisconsin is limited. According to the reports of the United States engineers there are some rapids at the mouth of Eagle river, about 24 miles below Lac Vieux Desert, called Otter rapids. It is proposed to build a dam at the head of these rapids, creating a reservoir, and it is said that "the water can easily be raised 22 feet". From the head of the rapids down to about a mile above the mouth of Pelican river, a distance of about 35 miles, the total fall is stated in the above report to be only 57 feet, or about 1.63 foot per mile; but those familiar with the river state that there are numerous small rapids and much available water-power down to near Jenny, where the heavy rapids begin. The entrance of the Tomahawk river increases the tributary area from 1,397 to 2,111 square miles, and adds very materially to the volume of the main stream.

In the section from 15 miles above Jenny down to Point Basse there are seven principal rapids, namely, Grandfather Bull rapids, Big Bull rapids at Wausau, Little Bull rapids at Mosinee, Stevens Point rapids, Conant's rapids (just below the last place), Grand Rapids, and Whitney's rapids at and above Point Basse. Some of these are very heavy. Grandfather Bull rapids, which are 15 miles above Jenny, are the heaviest rapids of the Wisconsin, the total fall being 105 feet in a distance of $1\frac{1}{8}$ mile. The river is about 500 feet in width, and divided at the head of the rapids into three channels by two rocky islands, which rise 10 or 15 feet above the water and extend some distance down stream. The bed and the banks of the river consist of varieties of granitic rock. The descent is largely distributed in small falls from 2 to 7 feet and from 150 to 300 feet apart.

There are two small rapids 6 and 12 miles, respectively, above Grandfather Bull rapids, and at Jenny are Beaulieux's rapids, now improved. Below are Trap rapids and then Wausau. The section 25 miles long from Wausau to Knowlton, below Mosinee, has an average descent of about 4 feet per mile, and the greater part of the fall is concentrated in Big Bull rapids. From Knowlton down to Stevens Point the total fall is 39 feet in 20 miles. In the 20 miles from Stevens Point to Grand Rapids the total descent is 64 feet, or 3.2 feet per mile, and this includes Conant's rapids, which are said to have a fall of some 30 feet in 2 or 3 miles. For the last 15 miles above Point Basse there is a long series of rapids with intervening reaches of quiet water. The amount of descent in this distance is not known. These rapids, included in the Archæan region, are over hard metamorphic rock, which furnishes excellent foundations for dams and other structures.

Improved powers.—There are in all six improved powers on the Wisconsin, all between Jenny and Point Basse, in the order given below. A personal visit was made to Jenny, Stevens Point, and Grand Rapids; for the other rapids between these places information was obtained by interview:

Jenny.—The first is at Jenny, where on the left bank is a saw-mill, using 260 horse-power, and on the right bank a grist-mill, using 50 horse-power, both under a head of 11 feet.

Wausau.—At Wausau there are a number of rocky islands, composed of syenitic granite, between which the water rushes in heavy rapids, forming Big Bull rapids. The dams cross to the islands, and a head of 12 or 13 feet is used. There are three saw-mills, each with four circular saws, a gang-saw, and a planing-mill attached. There is also a grist-mill with four runs of stones. The total power used is about 500 horse-power.

Mosinee.—At Little Bull rapids the river is divided into two channels by a rocky island, about a quarter of a mile wide. The main portion of the river passes through the eastern channel, which is stated to be only 35 feet wide for a distance of 135 feet. The rock is syenite. The water is carried down the island in a race, and supplies a saw-mill, a planing-mill, a grist-mill of two or three runs, and a small tannery, under a head of about 12 feet. The total power used is about 200 horse-power.

Stevens Point.—At Stevens Point the river is about 600 feet wide, which is above the average. The dam extends all the way across the channel, and the mills are on the left bank. They comprise a saw-mill directly at the dam, and a grist-mill adjoining; also a flouring-mill, about 200 feet back from the river-bank. The head used is 6 feet at all the mills.

The power originally belonged to a person connected with the saw-mill. He sold 4,000 "inches" of water to the flouring-mill, but still retains the remaining flow of the river. The saw-mill has three wheels, using altogether 3,700 "inches" of water; the grist-mill has two wheels, with a combined capacity for 1,500 "inches"; and the 4,000 "inches" owned by the flouring-mill drive three runs of stones and two sets of rollers. The total flow disposed of is, consequently, 9,200 "inches." The owner of the unemployed power considers that only about one-third of the low-water flow of the river is in use. According to the method of estimating discharge, 9,200 inches under a head of 6 feet gives a flow of 1,250 cubic feet per second. Adopting the ordinary low flow of 0.39 cubic feet per second per square mile for the area above Stevens Point, gives a volume of flow of 1,970 cubic feet per second.

The bed and banks of the river are solid rock, consisting chiefly of gneiss. There are rapids below the dam, and probably at least 2 feet of additional fall is available down to the railroad bridge, which crosses the river some 1,500 feet below. Each bank is flat, and apparently in excellent condition for extending a race down it. Five or six feet is a very high rise in the pond, but this is a wide place in the river. A side-track from the railroad passes near the mills on its way to the steam saw-mills, a third of a mile up-stream.

Just below Stevens Point begin Conant's rapids. They are unimproved, but afford many good sites to be developed. As before mentioned, there is a reported fall of about 30 feet in a distance of 2 or 3 miles. The rock consists chiefly of varieties of gneiss and syenite.

Grand Rapids.—The town of Grand Rapids is situated on the left or east bank, and Centralia is directly opposite. The rapids extend about half a mile below, and for about 3 miles up-stream there is more or less rapid water, but the main rapids are at the towns. There, for a distance of about a mile, from the Green Bay and Minnesota Railroad bridge down to the highway bridge between the two towns, the river spreads out to a width of about 1,000 feet, and rushes down between rocky islands and spurs of gneiss rock, with an estimated total fall of 25 feet. All the power used is on the Centralia side of the river, where there are a flouring-mill, a saw-mill, and a shingle-mill. In former years, when Grand Rapids was in the center of the lumber trade, there were mills on the east side of the river, and the ruins of an old race, a saw-mill, and one or two other buildings yet remain.

This power on the Grand Rapids bank could be once more improved. The bank is rocky, and rises steeper than on the other side, but would not prevent the utilization of the power. On the west or Centralia side there is a good level bank, and the full resources of the place could be improved. At present there is only about 300 horse-power in use, of which the flouring-mill takes 150 horse-power under a head of 11 feet, the saw-mill 100 horse-power under the same head, and the shingle-mill 50 horse-power under a head of 8 feet. The flouring-mill has six runs of stones and several sets of rollers. The wheat and corn are obtained chiefly from Minnesota and Iowa.

It has been proposed to build a paper-mill at Centralia, and undoubtedly if this is done a pulp-mill would form part of the establishment. There are great quantities of poplar wood growing along the Wisconsin and its tributaries which would be of value to the paper manufacture.

The river above the railroad bridge consists of several channels, and of these it is the one furthest west which supplies the water-power at Centralia. This power is owned by the proprietor of the mill at that place, and it is claimed that about one-half the ordinary discharge of the river passes through this west channel. This would give, according to our estimates, an ordinary low flow of 1,043 cubic feet per second, which under a head of 25 feet gives 2,960 theoretical horse-power.

Port Edwards.—The next and last improved power on the river is at Port Edwards, about half way between Grand Rapids and Point Basse. Mention has already been made of the succession of rapids and slack-water in that locality; and there is, undoubtedly, a great amount of power available in addition to the small amount used by the one saw-mill there, which takes 500 horse-power under 10 feet head of water.

At Point Basse is the limit of the region of rapids, and the river enters upon the lower section, where it flows over softer sedimentary rocks. So far as could be ascertained, there is no really available site for water-power in the entire distance down to the mouth, with the exception of the Dalles.

Water-power at Kilbourne City.—Kilbourne City is at the lower extremity of the Dalles of the Wisconsin, and at this point there is an available power, which was at one time in use, the nearest to the mouth of all the water-powers on the river.

Seven or eight hundred feet below the Chicago, Milwaukee and Saint Paul Railroad bridge the river takes a bend to the east, and emerges from the Dalles, which there consist of cliffs of light-yellow and gray sandstone from 30 to 50 feet high. The channel of the river is 400 or 450 feet wide at the bend.

A few rods above the bend are the remnants of an old dam, over which the water rushes in strong rapids, a favorite resort of the Indians, who at the proper season come long distances to spear sturgeon for their winter's food.

The history of this old dam is as follows: About 1857 a charter was obtained for the erection of a dam at this point, with a height of 3 feet above low water. It was erected with a height of 8 feet. Subsequently part of it was washed out and was afterward rebuilt. The rafts were badly broken up in passing over the dam, and finally a large party of lumbermen came down-stream in force, and by cutting and blasting succeeded in tearing away all the dam down to low-water mark. About 1866 the dam was rebuilt with the 3-foot head allowed by the charter, and a flouring-mill erected on the east bank of the river directly at the abutment of the dam. This was burnt by incendiaries, and since then nothing has been done with the power. The greatest opposition was from the Yellow River lumbermen; their rafts had no dams to pass except this one, and hence were not so well provided with spring-poles, etc., as those from farther up the river; consequently, they were very liable to be destroyed.

Since the introduction of railroads most of the lumber is shipped by them, and so few rafts pass down the river that it is thought little objection would be now raised to the utilization of the water-power. The situation is excellent as regards facilities for transportation, because of the vicinity of the railroad.

Although the original head allowed by charter was only 3 feet, it is probable that little objection would now be made to raising the dam so as to give a head of 8 feet or even more, which is possible, as the raising of the dam

would merely back the water up the Dalles. The dam as it now exists could be made the foundation for a new one. By building a bulkhead at the east end, where the wheels of the old mill were placed, it is probable that the 3-foot head could be restored with a cost of from $1,000 to $2,000.

The dam was so substantially built as almost to defy the efforts of the lumbermen to destroy it. The following description was given of its construction: First, a crib of oak timber, dovetailed together, 80 feet wide at the base, 10 feet high on the lower side, and only 2 feet or so high on the upper side, was built across the river on the ice, steadied with poles, and then sunk with stones into its place. Then on the crib were laid oak trees in rows with their branches on, the butts pointing down-stream. There were two or three lengths of these in the course, the butts of one length resting on the branches of the other. The course was then weighted with stone, cross-timbers were placed across the rows of butts, and the process was repeated.

The chief disadvantage of the locality is the limited space for utilizing the power. However, the sandstone cliff could be cut away, as was done for the old mill, and a race could be carried along it. This would be expensive, and would only be warranted, if at all, by the erection of large establishments. Part of the power could be now used with comparatively little expense, from the site of the old mill.

TRIBUTARIES OF THE WISCONSIN.

There is considerable power utilized on the branches of the Wisconsin, especially in the southern portion of the basin, where the Baraboo and the Kickapoo, with numerous smaller streams, supply power to a large number of mills. The water-shed line is 200 or 300 feet above the main stream on each side, and as the tributaries have to fall this distance within their comparatively short lengths, they have many rapids and available powers.

The larger tributaries, as measured on the Land Office maps, average 50 or 60 miles in length, and hence have an average fall per mile of 4 feet or more. As with the upper portion of the main river, many of the rapids are over the hard granites and allied rocks which underly that region. The streams in the upper portion of the basin have no developed powers.

TOMAHAWK RIVER

Reservoir surveys have been made on the Tomahawk, and their records make mention of a rapid 1,500 feet above the mouth, where the river falls 19 feet in the course of a mile, and of another rapid 10 miles from the mouth, with a fall of 75 feet in 450 feet. The current of the river is usually swift.

Among the rivers which have been at least partially improved, the Baraboo ranks first, with, according to the census returns, 851 utilized horse-power, and next the Kickapoo, with 567 horse-power.

The Lemonweir river has 186 horse-power in use, the Eau Claire river 120 horse-power, and the Rib river and Little Rib river together are credited with 266 horse-power.

YELLOW RIVER.

The Yellow river has 96 horse-power developed, but there are several small tributaries which have more water-power in actual use. The Yellow river has the greater part of its descent in its upper section, where, like the upper Wisconsin, it flows over the metamorphic rock; near its mouth it runs across sandstone strata and is rather sluggish. There is a vast amount of undeveloped water-power on the stream.

LEMONWEIR RIVER.

The Lemonweir has three flouring-mills, using 50, 34, and 20 horse-power, respectively, under heads of from 5 to 8 feet; and two saw-mills, with 57 and 25 horse-power, and heads of 6 and 8 feet, respectively. The source of the river is a swampy, level region of light soil, with meadow and brush growth, and the stream is considered rather steadier in its flow than the Yellow river.

BARABOO RIVER.

The Baraboo is prominent among the water-power streams of the Wisconsin basin. It rises at an elevation of nearly 1,200 feet, and in the distance of 70 or 80 miles to its mouth falls 400 feet, or about 5.3 feet per mile. The rapid descent gives opportunity for a large number of available powers, and as the stream flows through a settled region, these are extensively used. The Baraboo strikes the northern one of the two eas ward-trending quartzite ranges, called the Baraboo ranges, penetrates it, and, after flowing in the intervening valley for 15 miles, once more passes through the northern ridge, and then enters the plain of the Wisconsin valley near Portage. The hard rock encountered causes many rapids.

The number of establishments using the power of the Baraboo is large, comprising 11 flouring-mills, using 580 horse-power, 5 saw-mills, using 123 horse-power, and 5 miscellaneous establishments, such as machine-shops, furniture factories, etc., using 148 horse-power.

The largest power used by one establishment is 168 horse-power under a head of 10 feet, driving the machinery of a flouring-mill. The highest head used is 22 feet, and the average is from 10 to 12 feet. A fall of 10 feet on the lower part of the river gives about 200 available horse-power.

KICKAPOO RIVER.

The Kickapoo river is the last tributary of any considerable size entering the Wisconsin. There is a large amount of fall in its course, and, as in the case of the Baraboo, the power is extensively utilized. Next to the Yellow river it drains the largest area of all the branches of the main river. There are 8 flouring- and grist-mills upon the river, using 224 horse-power, and 11 saw-mills, using 343 horse-power. The head of water used does not average so high as on the Baraboo, being only about 8 feet, while the greatest head recorded is 12 feet. There are no other industries taking the power of the Kickapoo river.

THE CANNON, ZUMBRO, ROOT, UPPER IOWA, AND TURKEY RIVERS.

Because of their general similarity, the three great rivers of Wisconsin have just been discussed in succession, and now, going back to the west side of the Mississippi, where we left it at the mouth of the Minnesota, the first stream to engage our attention is the Cannon river.

A glance at the map will show that the important streams entering the Mississippi in Minnesota below the Minnesota river are, in order, the Cannon, the Zumbro, and the Root rivers, and, continuing into Iowa, the upper Iowa and Turkey rivers, which last enters the Mississippi below the Wisconsin, about half way between it and the state line separating Illinois and Wisconsin.

Below the Turkey river, in Iowa, are the Maquoketa and the Wapsipinicon, which are reported upon by Mr. Dwight Porter, special agent of the census.

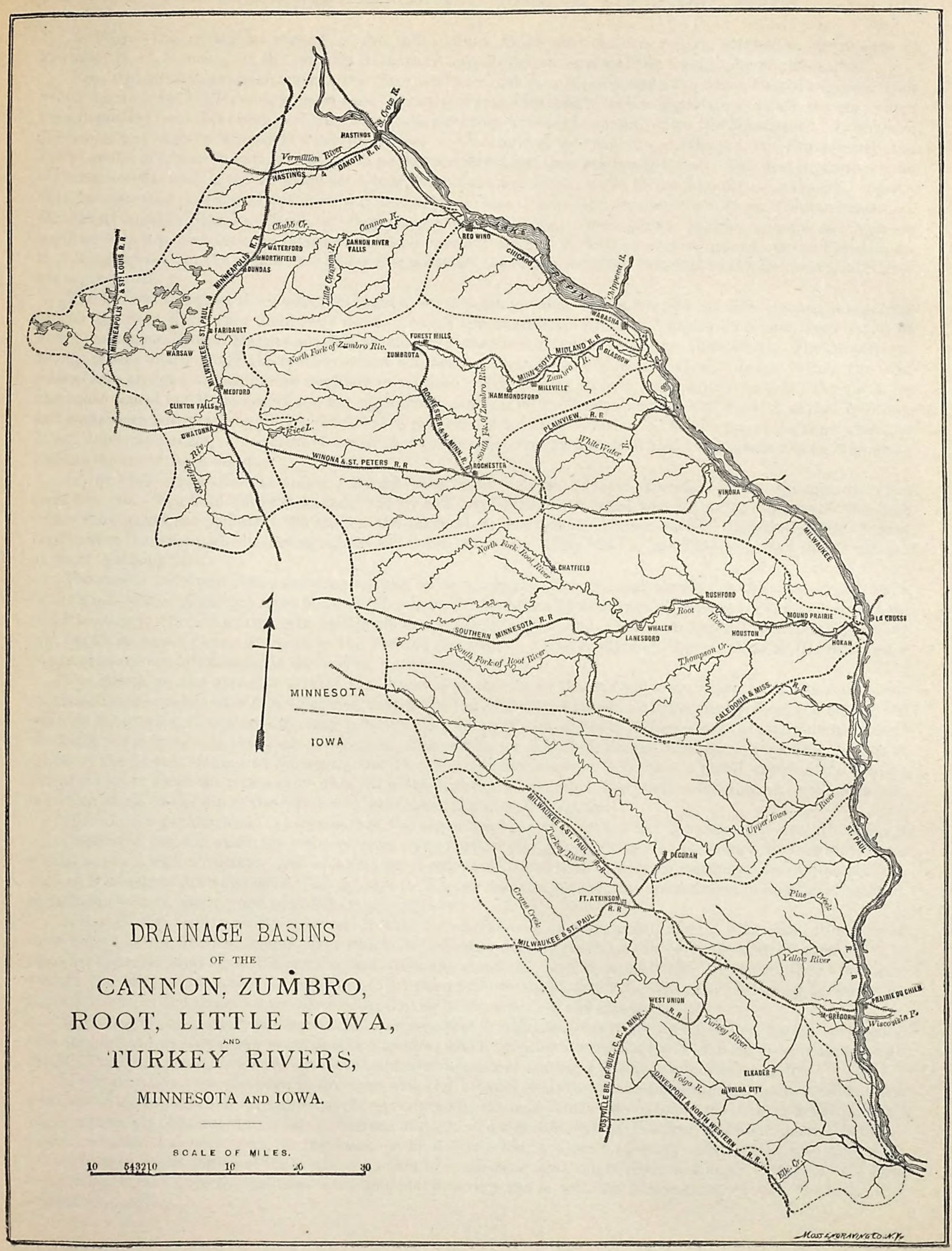
The discussion of the five rivers mentioned at the heading of this section will complete the report on the tributaries of the Mississippi down to the southern limit of the state of Wisconsin, and because of the many characteristics which these five streams possess in common, a general description will apply to all their basins, with a statement afterward of such special details as are available.

GENERAL DESCRIPTION OF THE RIVERS AND THEIR BASINS.

The section of land under consideration is a strip averaging 50 or 60 miles wide, and 150 miles long, extending along the west bank of the Mississippi from the southern line of water-shed of the Minnesota River basin down to the limits of the Maquoketa and Wapsipinicon River basins in Iowa. Of the five rivers which, for the most part, carry its drainage to the Mississippi, the most northern one, the Cannon, has a general northeast direction; the southern one, the Turkey, has a southeast course, while the remaining three, the Zumbro, the Root, and the upper Iowa, flow almost directly east. The drainage area is quite uniformly distributed between them, as shown by the following figures:

	Square miles.
Cannon river	1,492
Root river	1,609
Zumbro river	1,346
Upper Iowa river	952
Turkey river	1,725

As may be inferred from the limited extent of drainage belonging to each of these rivers, they are not of large size, but they derive considerable importance from the extent to which their water-power is utilized, chiefly by flouring-and grist-mills. The census returns show that there is a total of about 9,300 horse-power in use in the region. This is primarily due to the existence of available power, but it is also owing to the condition of settlement of southern Minnesota and Iowa. Numerous towns are scattered over the land, and various branches of the Chicago and Northwestern and of the Chicago, Milwaukee, and Saint Paul railroads run north and west across the region. The land is largely cultivated, and embraces very fertile regions. Most of the winter wheat grown in Minnesota comes from there, and in proceeding south the soil becomes somewhat lighter, assuming more of the characteristics of the loam on which the corn of Iowa is raised. Westward, about the headwaters of the streams, the surface is undulating or only slightly broken by the channels of drainage; but in journeying eastward, toward the Mississippi, a change is noticed; the country is broken, and even hilly, though back from the ridges and bluffs are sometimes extensive stretches of undulating land, and the general level above the valleys is nearly uniform. The small streams, as well as the main rivers, run at the bottom of large valleys several hundred feet deep. These valleys finally unite along the main lines of drainage, and then emerge into the great trough of the Mississippi, 400 or 500 feet, or even more, below the general surface. The succession of cultivated land, prairie, and woodland, broken by the bold bluffs and ridges, presents some of the most charming views of that part of the Mississippi basin. The abrupt hillsides, rising in some places over 500 feet above the Root river, give a character to the scenery along the Minnesota Southern railroad which is a surprise after the experience of the prairie north and west.



DRAINAGE BASINS

OF THE

CANNON, ZUMBRO, ROOT, LITTLE IOWA, AND TURKEY RIVERS,

MINNESOTA AND IOWA.

SCALE OF MILES.

10 5 4 3 2 1 0 10 20 30

Geology.—The geological reports of the three states which meet in this region, especially the reports of Professor N. H. Winchell on the counties in southeastern Minnesota, treat of the topography and its causes.

Frequent allusion has been made to the rib of Archæan rock running east and west, which formed the coast upon which the waves of the Palæozoic ocean used to beat, and to the successive layers of sandstone, limestone, etc., which were deposited from this ocean, and whose successive outcrops are met in passing down the Mississippi. In western Wisconsin and eastern Minnesota there was a deep indentation of the coast-line northward, and consequently the line of strike of the sedimentary rock strata passes northwest and then bends southwest. The first layer above the old metamorphic rock is the Potsdam sandstone, which reaches north almost to the lake Superior trough. Above that, in succession, are the following strata: Lower Magnesian limestone, Saint Peter sandstone, Trenton limestone, Cincinnati shales, Niagara limestone, Devonian, Cretaceous, etc. These strata have a general southern or southwestern dip, and hence in their general relations they are met in their successive order from the Potsdam up in passing south. In the region now under discussion all the strata, from the Potsdam to the Devonian, inclusive, are represented.

The ancient trough of the Mississippi is cut down into the Potsdam sandstone, and the side streams, in reaching it from the west, have worn their beds down through the successive strata of Niagara limestone, Trenton, Saint Peter sandstone, Lower Magnesian, and so on, until they reach the level of the Mississippi. The Mississippi trough passes nearly along the northwest and southeast strike of the strata, and these tributaries from the west pass nearly at right angles across the lines of outcrop. The Turkey river is an exception to this rule; for in its southeast course it follows nearly the line of outcrop, running in the Galena limestone (a division of the Trenton), and sometimes cutting through into the Trenton proper. It is to their erosion in these rocks at the time when the Mississippi was cutting its ancient channel, that the broken country and deep valleys of southeastern Minnesota and northeastern Iowa are due.

In the bluffs which line the valley are sometimes to be seen two or more successive strata through which the river has cut. The hard limestones, underlaid by soft sandstone, have acted to give an abruptness to the cliffs which they would not possess if the erosion had taken place in a homogeneous material. Especially is this true of the Trenton limestone, which, resting on the soft Saint Peter sandstone, has had precisely the effect that is noticed at Saint Anthony falls.

The rapids and finest water-powers generally occur where the streams break across the limestone strata, while in the sandstone regions they have a comparatively uniform slope. Thus most of the rivers are more sluggish near the Mississippi, where they run over the Potsdam sandstone region, and hard rock does not characterize the bed and banks as in the places occupied by the Trenton limestone. These sandy and loam sections of the rivers offer comparatively few advantages in the way of water-power.

The rivers on the opposite side of the Mississippi, the Saint Croix, Chippewa, Black, etc., also have their sandstone sections, but with this difference, that, while the sandstone extends a comparatively short distance up the western tributaries, it appears for many miles up the valleys of the rivers of Wisconsin, practically limiting their available water-powers to the Archæan section. The reason for this is plain: the Mississippi runs near the line of strike of the Lower Magnesian limestone, and leaves to the northeast in Wisconsin a broad expanse of Potsdam sandstone, over which the rivers run with a fall in the direction of the dip. The western tributaries, on the contrary, fall at an angle to the dip of the strata and pass them in a shorter distance.

There is one peculiarity of a large part of the region between the Turkey and the Cannon rivers, which has a very important bearing upon the water powers. The surface of the northwest was covered with drift during the glacial age—as with a blanket—and to a very great extent all traces of the earlier topography were obliterated, the ancient channels of drainage were filled up, and to this day many of the streams are engaged in re-excavating their beds from the clay, gravel, and sand left by the glaciers.

Although the drift is nearly universal in this region, there is an area in Minnesota, Wisconsin, Illinois, and Iowa known as the driftless region, over which the ice mass did not reach, or the covering of drift spread. It is bounded approximately by a line running east from the mouth of the Chippewa to the Wisconsin, then south and west to the Mississippi, about 15 miles south of the northern limit of Illinois, and then northwest, crossing the upper portions of the rivers we are discussing, and so to the mouth of the Chippewa.

The cause of the glaciers passing around this region is thought by some to have been the projecting rib of hard rock terminating in Keweenaw point in lake Superior, which acted as a wedge to divide the ice mass in its passage south. Professor Dana attributes it to local climatic variations, causing a smaller accumulation of ice.

In the driftless area the lines of drainage and the broader features of the topography remain much as they were before the ice age, and the ragged surface produced by the long-continued erosion of the streams is not rounded off, or completely obliterated by a thick covering of drift. To a certain extent, however, a similar action has taken place. Allusion has been made to the loess, or bluff formation, a deposit of finely comminuted clay and loam settled from the quiet waters of the inland sea which once occupied the basin of the Mississippi. This was deposited to a certain extent over the driftless area, and makes a very fertile soil, but is not thick enough to destroy the ancient topography.

Along the upper waters of the rivers, up to the Cannon, the eastern margin of the drift merges into the loess formation, and west of that the rivers have the characteristics of the prairie streams, which have their beds in the drift, rapids, if there are any, occurring over accumulations of bowlders; but east of the limit of the drift are met the rock-bed and banks and the deep valleys previously described. The Cannon river lies a little north and west of the driftless region, as marked upon the maps, but nevertheless reaches the solid rock before it has passed over more than a third of its course.

Flow.—The five rivers considered do not have the natural reservoirs to draw from in low water which characterize the streams draining northern Wisconsin and Minnesota. No lakes and tamarack swamps store the rains and deal them out gradually during the dry months, and there are no unbroken forests to check evaporation. But they do not belong at the other extreme of the series presented by the upper Mississippi basin, and if they cannot be classed with the Leech lake region and its neighbors, no more can they be fairly classed with the prairie drainage at the headwaters of the Minnesota. Their position is midway between the two. There is more or less timber-land along the valleys and in groves, and numerous springs trickle out along the sides of the bluffs. A large number of these springs is due to a layer of impervious shale in the midst of the Trenton, and where that comes out along the face of the bluff a line of springs is often noticed. (*a*)

The great number of lakes found in Minnesota is due to the depressions and basins left by the glaciers—basins which have not yet been filled up or drained by erosion. These do not exist in a country unmodified by glacial action, and hence the very few lakes found in the region or at the sources of the rivers where they rise in the drift country. The Cannon river may be considered the only one fed by lakes, and has several of shallow depth in the upper part of its course.

The Big Woods, which cross the basin of the Minnesota below the great bend to the northeast, send their outposts into the region drained by the Cannon. So far as can be ascertained, the five rivers owe what reputation they have for regularity of flow mainly to the many springs which feed them. "Bluffy streams", they are called by the millers. No gaugings of their discharge are available—merely the estimates of millers as to the power ordinarily obtainable from them; and while that is of practical value in estimating their capacity for manufacturing, it is a very rough way of determining the actual flow. However, after comparing with other streams, and with these millers' estimates, from 0.28 to 0.38 cubic foot per second per square mile was fixed upon in the tables for the average ordinary low flow, and 26 to 28 per cent. of the annual rainfall for the average yearly flow, the average annual precipitation varying from 29 to 32 inches. The true amount may be considerably greater or smaller than this, but that is the conclusion reached after a consideration of the circumstances of the case.

Fall.—The country west of the Mississippi in southern Minnesota and northern Iowa is at a high altitude, and the sources of the principal streams are at a height varying from 1,100 to 1,400 feet above the sea. To reach the Mississippi at an altitude of about 625 feet above sea-level, they have to descend from 500 to 700 or 800 feet; and as this fall takes place within distances varying from 80 to 100 miles, it is apparent that a rapid descent is to be found in them. A part of this is often concentrated in rapids and falls in the limestone sections.

The bluffs along the Mississippi and the lower parts of its tributaries are from 400 to 500 feet or more in height, and the descent in the streams is due, not to a rapid slope in the general surface of the country, but to the fall in the valleys which they have eroded. A good idea of the profile of the country in an east-and-west direction is given by the levels of the Minnesota Southern railroad, which passes up the Root River valley for 43 miles to Whalen, and then continues west.

Starting from the Mississippi, in which the low-water elevation is about 625 feet above the sea, the railroad rises to an altitude of 786 feet at Whalen; then at Fountain, 59 miles from the Mississippi. it is 1,302 feet above the sea, having risen 400 feet in the last 6 miles while ascending from the valley; then it runs along for some 25 miles at varying elevations, finally reaching the summit level, 90 miles from the Mississippi, at an elevation of 1,412 feet above the sea, and then descending to the Cedar river.

CANNON RIVER.

The Cannon rises about 25 miles north of the southern boundary of Minnesota, and after a course of 90 miles (map measurement) enters the Mississippi 21 miles below the mouth of the Saint Croix river. Its general course is a regular curve, convex toward the northwest. Nominally, the Cannon rises in the western part of the basin, and the stream, 43 miles long, which flows from the south, is called the Straight river, uniting with the Cannon at Faribault. Practically the Straight river is a continuation of the Cannon. It was called by the Indians Owatonna, meaning straight; and it is thought that this name must have been given in a spirit of irony, as it is a very crooked stream.

The Cannon, as previously mentioned, rises in the drift and flows through it, but has cut down to the rock below, forming rapids with solid banks and bed, and offering good water powers.

The Straight river first succeeds in cutting through the drift and reaching the bed-rock just below the town of Owatonna, about half-way between its source and Faribault. There it strikes the Trenton limestone, and thence down to the Mississippi the river runs below the level of rock outcrop.

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a See *Geological Report of Minnesota for* 1876.

In crossing Rice county, from south to north (Faribault is situated in the southern half of the county), the river completes its excavation through the Trenton formation, cuts through the Saint Peter sandstone, and penetrates 30 feet into the Lower Magnesian limestone, descending about 150 feet in a distance of some 20 miles. Then it continues through the Lower Magnesian strata, and comes out upon the Potsdam sandstone. Above Owatonna the Straight river is not so rapid, and has no improved powers. Below Owatonna there are several powers, and, besides the number of improved sites, there are a number of available ones which yet remain to be developed. From a few miles below Cannon River falls, which are about 20 miles above the mouth of the river, down to the Mississippi the bed and banks are of earth, and more or less flowage would be caused by dams. The town of Cannon River Falls probably marks the locality where the river leaves the Lower Magnesian limestone and enters upon the softer sandstone below. As a general rule the bed and banks of the river consist of gravel or clay, but at places a solid rock bed is found.

The lakes feeding the Cannon drain into it before the junction with the Straight river at Faribault, and serve to make it more steady in flow than the latter stream. There is some idea among the mill-owners of establishing a system of reservoirs out of these lakes and still further regulating the discharge. They claim that according to survey 587,000,000 cubic feet could be stored by raising the level of the lakes 2 feet. This would give a discharge of about 75 cubic feet per second for three months. Tho Straight river has few lakes, and diminishes in winter and dry seasons so that three out of the five mills upon it have steam-power as an auxiliary to their wheels.

At Faribault, where the two streams unite, it is not considered advisable to build more than a six-run mill, with a head of 10 feet, although during part of the year many more runs could be operated; but during a severe winter there might not be sufficient water to run them at all. Using the estimate for ordinary low flow given in the tables, with the understanding that it does not apply to the winter months, gives a discharge at the mouth of 433 cubic feet per second, furnishing, under a head of 10 feet, 491 theoretical horse-power.

Utilized powers.—Starting with the Cannon above the junction with the Straight river, the first power from the source is at Waterville, where there was once a mill with four runs, under a head of 5 feet. It was burnt down, and the power is unused. Below is Morristown, where there is a custom mill, with 7 feet head of water. One mile below is a locality unimproved, where, by cutting across a neck of land, a head of 12 feet can be obtained. Next is the Warsaw dam, giving a head of 4.5 feet, which could be increased to 6 feet, but there is no mill there now. Then comes the Polar Star flouring-mill, at Faribault, with a head of 9.5 feet, and a capacity of from 200 to 300 barrels of flour per day. Steam is used part of the time.

The mills on Straight river are these, from the source to Faribault:

Owatonna mill, 5.5 feet head; Clinton mill, 8 feet head; Walcott mill, 10 feet head; "Straight River stone mill," 9 feet head; the Green and Gold mill, 8 feet head. The three upper ones each use 40 horse-power, and the remaining two use 60 horse-power each. All but the upper two use steam also. There are a number of unimproved powers, offering a head of from 7 to 13 feet, which can be made available.

Below the junction of the Straight and Cannon, at Faribault, there are the following powers:

Scotte's mill is 3 miles below Faribault, and has a head of 8.5 feet. Above it are two unimproved locations where a head of 9 feet is obtainable.

About 1.5 mile below Scotte's mill is an unimproved power with a head of 7 feet, and about 2 miles beyond is another of 9 feet. The next mill is at Dundas, where there is a head of 9 feet, and a daily product of 185 barrels of flour; then the Northfield mill, with a head of 10.5 feet, and a capacity of 300 barrels per day.

Below this there are four mills with heads ranging from 7 to 13 feet.

The power at Cannon falls is fine, but unimproved; a head of at least 20 feet is available. There is unimproved power both above and below, but for the lower half of the distance down to the mouth there is little, if any, available power.

The census returns show that several of the mills have steam-engines for use during low water. According to the returns there is a total of 1,220 horse-power in use on the Cannon and Straight rivers, all being used by flouring- or grist-mills, with the exception of 6 horse-power, taken by a small machine-shop.

There are several small tributaries of the Cannon, as Little Cannon river and Belle creek, which have one or two small mills upon each. Some brooks fed by springs furnish small mills with very reliable power. Spring brook, for example, enters near the mouth, and supplies four or five such mills.

ZUMBRO RIVER.

This stream enters the Mississippi 7 miles below the mouth of the Chippewa, after a general easterly course through a basin 1,346 square miles in extent. The length, as measured on the map, to the farthest source, is about 80 miles. Some 40 miles from the mouth the river divides, the North branch flowing from the west, and the South branch from the south. About 8 miles south of the junction the South branch receives the Middle branch, which flows directly east. Near its head the South branch radiates into a number of small streams.

About two-thirds of the entire Zumbro basin is tributary to the river above the junction of the North and South branches. From the junction down to the mouth the basin is not more than 10 or 15 miles wide, and the side streams are small in size. Of the three branches the South and the Middle branches drain about equal areas, much larger than that tributary to the North branch.

The lower part of the river is in the driftless region, but the sources are in a country covered with drift. This, however, has not prevented the stream from cutting down to the rock; and all the branches, especially the South branch, soon strike the bed-rock. This occasions many available water-powers in the upper part of the basin, where the bed and banks are largely rock, giving good locations for dams. In the lower portion of the river the bed is mainly of gravel, and generally one bank is low, making the development of water-powers expensive. The valleys and bluffs characteristic of the region are found along the Zumbro and its tributaries.

There is a moderate amount of woodland in the Zumbro basin, but there are very few lakes, and the flow would be extremely unsteady were it not for the many springs which feed the streams. These come out of the bluffs, along the Trenton limestone, as previously described, and serve to some extent to maintain the low-water flow of the river. Nevertheless, it is not remarkable as a steady stream, and in severe winters the discharge is very much diminished. A few of the mills upon it have steam-engines to assist their water-wheels.

The following statement regarding the Middle branch is quoted from the *Geological Report of Minnesota* for 1876: "For three or four months in the winter of 1874–'75 the mills had no water. Some years, however, they continue to have water the year through. The water in the North branch is even more unreliable than this."

There is considerable fall in the river. The surface of the water in the Middle branch at Orinoco, 4 or 5 miles above its mouth, is 935 feet above the sea, and hence the total fall to the Mississippi is about 300 feet, or nearly 6 feet per mile. While there are some 15 or 18 improved powers upon the main river and its branches there are also several undeveloped sites, and these are mainly upon the branches. The main stream is expensive to improve, and has only one mill upon it according to the census returns.

Utilized powers.—The census returns credit the Zumbro and its three branches with a total of 707 utilized horse-power; all but 15 horse-power, used by a saw-mill, is taken by flouring- and grist-mills, working under heads varying from 7 to 17 feet, with the exception of the Mazeppa mill near the mouth, with a fall of 28 feet, which gives 105 horse-power, the others averaging from 20 to 30 horse-power under a head of about 11 feet. Three of the smaller-sized mills have steam-engines. Most of the mills are upon the Middle branch, which divides into two forks a few miles above its mouth. Upon the South branch there are only two mills. The mill at Rochester, on the South branch below the junction of its radiating branches, has four runs of stones under a head of 16 feet, requiring 65 horse-power. Steam is used, but the water-power is sufficient for four runs during nine months of the year, and during half the year many more runs could be operated. The other mill is three quarters of a mile below, and uses 100 horse-power under a head of 12 or 14 feet; no steam is used, but Bear creek enters above the mill and adds considerably to the power.

At Orinoco, on the Middle branch, there is a fine power with a head of 15 feet, which has been partly utilized by a feed-mill. The intention was to erect a flouring-mill of four and eventually of eight runs of stones. The existing mills on the Middle branch are mostly small, the largest using 75 horse-power under a head of 17 feet. The mill on the main river is at Zumbro falls, a few miles below the junction of the North and South branches, and is only a small mill of about three runs, under a head of 8 feet.

ROOT RIVER.

The basin of the Root river, 1,609 square miles in extent, is elliptical in general form, with the major axis extending east and west, and along this axis the river's course is located for about 45 miles, to where it divides, the South branch flowing from south of west and the North branch from north of west. About 20 miles above this junction the Middle branch flows into the North branch from the west. About half the entire basin is tributary to the river above the junction, and of this area the North and Middle branches together drain considerably more than the South branch.

The sources are in the drift, but the greater part of the basin lies within the driftless area, and some of the most striking scenery of the entire region is found along this stream. The different branches very soon penetrate to the rock, and before they unite have cut through the Magnesian limestone, reaching the equivalent of the Potsdam sandstone just above the junction.

Like the Zumbro, the Root owes what regularity of flow it possesses to the numerous bluff springs, and, so far as can be gathered from the opinions of millers, it is more steady than the former, maintaining its flow fairly well during summer and winter. None of the mills upon it use steam-power to assist their wheels in low stages. According to the statements of an experienced miller familiar with the stream, the ordinary capacity of each of the three branches is about 65 horse-power under a head of 10 feet. Where seen they each averaged about 50 feet wide, while the main river is from 200 to 300 feet in width. The bed of the river and its branches is largely rock, and one bank at least is usually high and firm.

There is a large fall in the Root river; the total descent from the extreme sources cannot be much less than 750 feet, or about 8 feet per mile. The greater part of this descent is concentrated in the branches, as the total fall below the junction is only about 161 feet, or 3.5 feet per mile.

Utilized power.—The Root river stands first in the list in point of developed water-power, and is not exceeded by any stream of its size in Minnesota or in Wisconsin. The census returns show that 1,344 horse-power is in use upon it, and of this all is taken by flouring- and grist-mills, with the exception of 27 horse-power used by a saw-mill, 5 horse-power by a blacksmith-shop, and the power used by two small woolen-mills. Many of the flouring-mills are extensive, having a daily capacity ranging from 200 to 400 barrels, and using from 100 to 200 horse-power. The head of water used varies from 6 to 12 feet, with the exception of one head of 22 feet. The largest mills are on the main stream, and there are eight of them, situated at the Junction, Whalen, Rushford, Houston, and Hokah.

On the South branch there are four flouring-mills, ranging from 50 to 175 barrels in capacity each, and a small woolen factory. On the Middle branch and its forks are five mills, all of small size, as the largest has a capacity of only about 75 barrels. On the North branch are four flouring-mills and a woolen factory. The largest mill is 2 miles below Chatfield, and has an average capacity of 150 barrels, under 15 feet head of water.

There are many fine water-power sites yet undeveloped; four or five occur in the 20 miles from the mouth of the Middle branch to the mouth of the South branch.

On the Middle branch are the Tunnel mills, where, by a tunnel through a rocky neck of land, a head of 30 feet is made available, and several localities are mentioned in the geological reports, where by similar tunnels even greater falls can be obtained. On the main river the fine sites are mostly developed. There is one valuable one affording a head of 12 feet at Peterson, 6 or 8 miles below the junction. The mill which formerly stood there was burnt down.

Many of the minor tributaries of the Root river have small mills upon them, and are very valuable for supplying the local demand for grinding. Some of these mills do merchant work as well.

UPPER IOWA RIVER.

This is the smallest of all the five rivers situated in the region under consideration, and drains 952 square miles, of which 180 square miles lie in Minnesota and the remainder in Iowa.

The river rises in Mower county, Minnesota, south of the sources of the Root river, flows southeast to Decorah, in Iowa, about 15 miles south of the state line, and then runs northeast to the Mississippi, meeting it about 3 miles below the line. It does not divide into several different branches, like the Root and Zumbro, but its tributaries are small brooks. The country through which it flows resembles the basin of the Root river to a great extent. It rises in the drift and cuts down through the successive strata to the Potsdam sandstone, leaving the Trenton a few miles below Decorah. The total descent cannot be far from that of the Root river, but it is not considered so rapid a stream. Like the rivers last discussed, its flow is largely maintained by springs.

There is only one mill in the first 20 or 25 miles from the mouth, and that uses only 25 horse-power, under a head of 6 feet. All the water-power used is on the upper part of the river. According to the census returns the total is 659 horse-power, but that does not include a small woolen factory at Decorah nor a paper-mill a few miles below. Nearly all the power is used by flouring-mills. The largest takes 150 horse-power, under a head of 11 feet, and the average is about 50 horse-power, under 9 feet head of water. The large mill is situated at Decorah.

The upper Iowa river is credited with a total of thirteen flouring- and grist-mills, of which two are situated in Minnesota. There is also a wagon factory using 20 horse-power. The side streams furnish a number of powers for small mills.

TURKEY RIVER.

The Turkey river rises about 6 miles south of the southern boundary of Minnesota, and south of the sources of the upper Iowa, and flows southeast 115 miles, by map measurement, to the Mississippi. The mouth is about half way between the mouth of the Wisconsin and the northern limit of the state of Illinois. The basin is 90 miles long, averaging 18 or 20 miles wide.

A stream about 50 miles long, called Volga river, enters from the west 20 miles from the mouth; and about 75 miles from the mouth Crane creek is received from the west. Crane creek is 50 miles long, and drains about the same amount of territory that the main river does above the junction.

The country drained by the Turkey river is similar in many respects to that through which the Root and upper Iowa rivers run. The valley of the lower river is deep and bounded by abrupt bluffs, but these decrease in size as one ascends the stream, until this is found running through the undulating prairie region, in which the timber is mainly confined to the water-courses, and where these have not succeeded in cutting far into the drift which forms the surface. In the lower part of the basin there are groves and some extensive bodies of timber.

The course of the river is parallel with the strike of the rock strata, and except at the sources it flows over the Galena limestone, a division of the Trenton, cutting through into the Trenton proper from a few miles above Crane creek down to the mouth of the Volga river. (*a*) This limestone, where not covered by drift, etc., forms excellent bed and banks for the erection of dams.

There are many springs feeding the river, and it is considered a rather steady stream.

At Elkader, 14 miles above the mouth of the Volga, where high rocky banks restrain the channel to what is not over the average width, the ordinary rise is from 4 to 6 feet, and during the extraordinary freshet of June, 1880, the waters rose only 12 feet. The available power at that place under a head of 10 feet is considered by the millers to be 225 or 250 horse-power at the lowest stage, and this agrees fairly with the estimate given in the tables, on the basis of 0.28 cubic foot per second per square mile for the ordinary low flow. According to the tables the power at the mouth, with the ordinary low flow under a head of 10 feet, is 548 theoretical horse-power.

The mouth of the river is 593 feet above sea-level, and judging from the altitude of the sources of the Root and the upper Iowa the source is probably 1,000 or 1,200 feet above the sea. This would make the total fall from 400 to 600 feet, or from 3.5 to 5 feet per mile.

A large part of the water-power of the basin is on the Volga river and Crane creek, and several mills are situated on each stream.

Utilized powers.—According to the census returns there is 906 horse-power in use on the Volga river, two saw-mills taking, respectively, 20 and 40 horse-power, and eighteen flouring- and grist-mills utilizing the remainder. Of these all but the Elkader mill are on the portion of the river above Clermont, which is about 10 miles below the mouth of Crane creek. Information was obtained of Thomson's mill below Elkader, a four-run mill under a head of 12 feet, which apparently is not mentioned in the census statistics. The mills are not very large; only three exceeding 60 horse-power, and these take 150, 90, and 80 horse-power, under heads of 12, 8, and 9 feet, respectively. The average is perhaps 45 horse-power under a head of about 8 feet.

There are six flouring- and two saw-mills on the Volga, using a total of 287 horse-power, the largest taking 64 horse-power under a head of 9.5 feet.

On Crane creek there are four flouring-mills, using a total of 118 horse-power. There are other tributaries of the Turkey river, as Otter and Elk creeks, which have a limited number of mills upon each.

ARTESIAN WELL WATER-POWER AT PRAIRIE DU CHIEN, WISCONSIN.

Prairie du Chien is a city of about 2,800 inhabitants, situated on the east bank of the Mississippi, about 3 miles above the mouth of the Wisconsin river. Between the river and the highland is a wide bottom, through which passes a slough filled with back-water when the river is high. From this slough rises a slope 30 or 40 feet in height, and then a wide terrace leads to the main bluffs of the Mississippi valley. On this terrace and slope the city is situated. A large 8-inch artesian well supplies the town with an abundance of water, which is carried through a system of street hydrants, and runs in profusion down the gutters of the main street. There are six wells in different parts of the place, and two of them are employed for hydraulic purposes.

Prairie du Chien is so situated that the rock strata mentioned in the last few pages have a south and southwest dip toward it, owing to the inclination of the Archæan base which underlies them. This is of course impervious to water, while the sandstones and some layers of the limestone above are easily penetrated. The lower member of the sedimentary series, the Potsdam sandstone or its equivalent, is underlaid by the granitic rock, and above it are the limestone and impervious shales of the Lower Magnesian. This sandstone has a broad surface exposed in Wisconsin and in Minnesota, and becomes charged with water, and it is to this water taken from the country northward that Prairie du Chien owes its artesian wells. They are not confined to this one locality; west in Iowa and east and northeast are many others.

There are two levels at Prairie du Chien at which water is struck, one at a depth of 1,000 feet and one some distance above, but the deep-seated wells appear to be the best. The opening of a new well very slightly diminishes the flow from the others. The deep wells are heavily charged with mineral salts, chiefly common salt and bisulphate of lime, which rust iron pipes.

The two wells used for water-power are very near the foot of the slope leading from the bottom-land to the terrace, and are owned by Mr. H. Weniger, the proprietor of the grist-mill which uses their power. The wells are about 50 feet apart, and have these dimensions: 5⅝-inch well, 1,012 feet deep; 8-inch well, 1,044 feet deep. After passing 118 feet of sand, and then 120 feet of shale, as the proprietor called it, water was struck, which increased in flow with the depth bored. The expense of the 8-inch well was $3 per foot, and of the other $2 per foot, making a total of $5,150. The mill is a small one of only two runs, using about 9 horse-power, only one run being operated at a time.

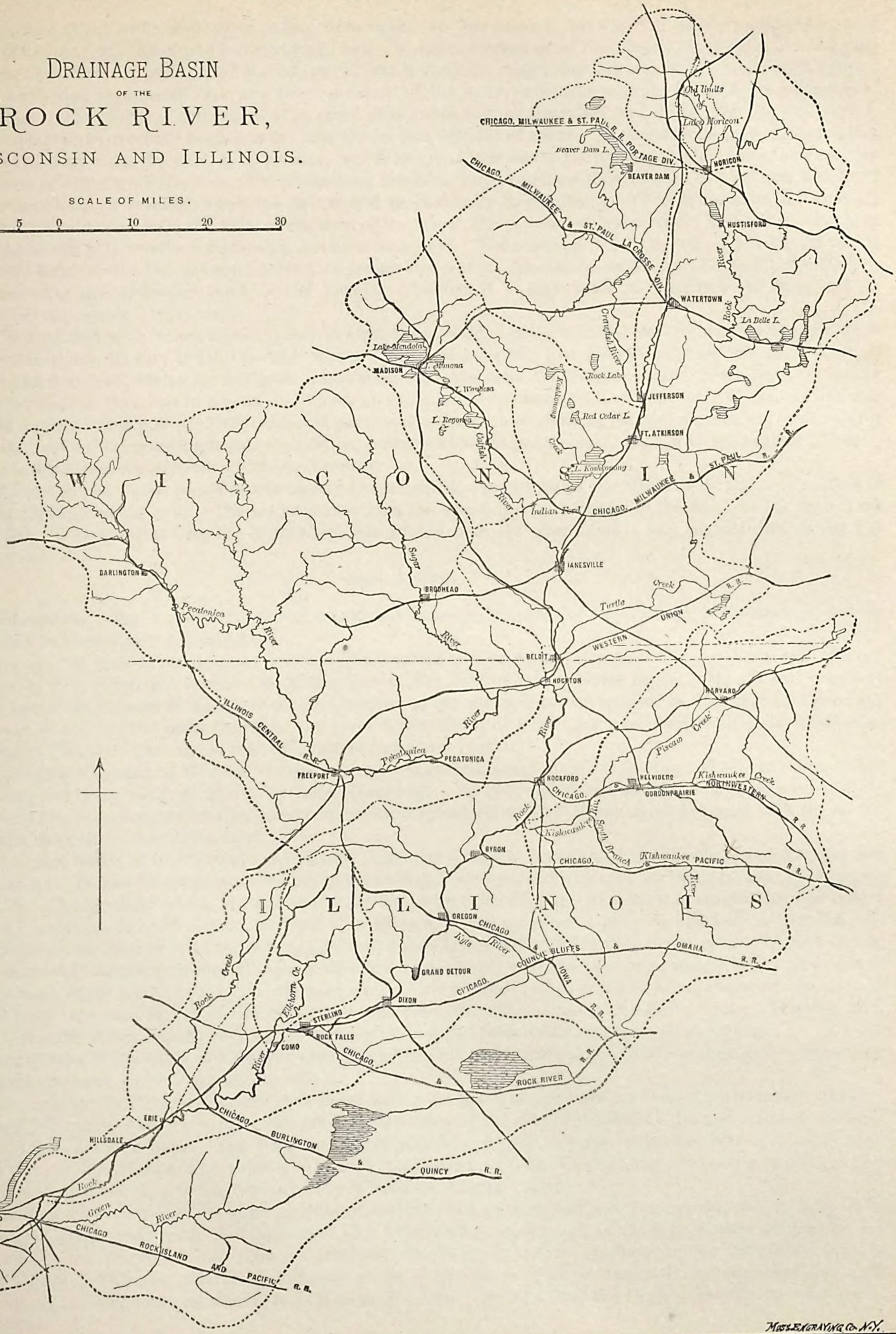
The method of taking the power is by transmitting the pressure of the two flowing wells directly to the wheel. Two iron pipes unite in a drum, 3 feet in diameter and 3 feet long, with its axis vertical, placed about 10 feet below

a Geological map of Iowa.

DRAINAGE BASIN
OF THE
ROCK RIVER,
WISCONSIN AND ILLINOIS.

SCALE OF MILES.

10 5 0 10 20 30



MOSS ENGRAVING CO. N.Y.

the earth surface at the wells, and 30 or 40 feet from each. In this drum is the wheel, 8 inches in diameter, with 120 inches of opening, manufactured in Dubuque, Iowa. It was the intention of the proprietor to erect a stand-pipe 35 feet high, and have the pressure of the column of water upon the wheel, but this would not increase the power obtainable over what is obtained from the direct pressure of the wells, except as it might increase the efficiency of the application. The height of the water in the stand-pipe would vary as the velocity of efflux from the well varied, and would equal the hydrostatic head less the head due to this velocity of efflux. In the same way, by transmitting the pressure directly from the well, as at present, this pressure is that due to the hydrostatic head less the head due to the velocity of efflux from the well. By diminishing the flow from the wheel the pressure can be increased until the hydrostatic head is reached, when the flow would be zero. By increasing the wheel-opening until it took all the flow which would come from the wells at the level of the wheel, the pressure of water would be diminished to that which would obtain if the wells were flowing freely at that level. The actual flow of the wells is not known, nor is the *hydraulic* head under the present method of using the water. The *hydrostatic* head is said to be 65 feet. Without knowing the hydraulic head or the velocity of efflux it is impossible to calculate the flow, but an approximation is possible in this way:

There is a 5⅝-inch well, whose mouth is 28 feet higher, and which has an intimate connection with the two wells under consideration. Its flow is 116,125 cubic feet per day, or 1.344 cubic foot per second, and this gives a rough means of estimating the discharge required. Assuming that the velocity of efflux at the lower level is that at the higher level, plus that due to a head of 28 feet, gives a discharge from a 5⅝-inch pipe of 7.443 cubic feet per second, and from an 8-inch pipe of 15.036 cubic feet per second. Hence, not allowing for friction, etc., the total natural flow from the two wells, according to this calculation, is 22.48 cubic feet per second. This, with the head of 28.9 feet, would give a total theoretical power of 74 horse-power.

There is gas in the water, but this acts merely to transmit the pressure, as the drum is air-tight. The flow is very steady throughout the year. The water passes from the wheel into the slough in the flat. In the high flood of June, 1880, the back-water from the Mississippi rose 16 feet over the wheel, but it only slightly diminished the power obtained.

ROCK RIVER.

General remarks.—The name of this river, translated into the language of the Indians, is Sinnissippi, and by this name it was known to the aborigines.

It rises in the tract of land lying between the sources of the upper Fox and the southern end of lake Winnebago, in Wisconsin, and enters the Mississippi at the foot of Rock Island rapids. Its general course is southwest and approximates to the arc of a circle, convex to the southeast, with a chord of 180 miles and a versed sine of about 30 miles. The total length of the river is 286 miles, of which distance nearly half is in Wisconsin, and the rest in Illinois. The source is in an extensive swampy region.

In 1842 a dam was built at Horicon village, forming a lake in this region, covering about 50 square miles, called lake Horicon, and lying south-southwest of lake Winnebago. In 1868 the dam was removed, on account of land damages, and the place has reverted to pretty much its original condition. Many maps yet exist with the shore-lines of lake Horicon marked upon them.

The drainage basin, of 10,973 square miles area, has 5,653 square miles situated in Wisconsin and 5,320 square miles in Illinois. It may be roughly described as pear-shaped in form, with the stem at Rock Island. The length is 175 miles. The greatest width is near the state line, where for 20 miles or more it averages about 80 miles; above that it averages 40 or 50 miles, while below, in Illinois, it soon narrows to 40 miles, and then to 25 miles.

In Wisconsin the river runs rather in the eastern side of its basin, but near the state line it approaches the center, which it follows for a distance through Illinois, finally flowing decidedly near the western boundary line of its drainage area. This basin of the Rock river is an undulating semi-prairie region. Large expanses of unbroken prairie, groves, and some more extensive bodies of timber, swamp, and lake, are all to be found within its limits. The soil, from southern Wisconsin down, makes very fine farming land, and has been cultivated from an early day.

The population of the basin in 1870 was 470,932, and in 1880 had increased to 485,578—a population, according to the census statistics, of 49.5 per square mile.

A large number of railroads intersect each other within the limits of the basin, and below the boundary between Illinois and Wisconsin there are nine independent crossings of the river by different lines of railroad, while in Wisconsin there are five more. The total number of places at which railroads cross the river is about twenty. Although this number might not be considered remarkable in some sections of the country, it shows a state of general industry more advanced than in the basins of the Wisconsin, Chippewa, etc.

Distribution of powers.—At a large number of the railroad crossings of the river are flourishing towns and cities, doing a good trade with the farmers of the surrounding region, and contributing more or less to the manufactures of the country, while some, as Rockford, for example, are conspicuous among the manufacturing centers of Illinois. This manufacturing industry of the Rock River basin is due to the water-power which the river affords all the way along its course, from the small stream emerging from the Horicon swamp almost down to its very mouth.

There are eighteen points at which the power of the river is in use, eight of them in Illinois, and at thirteen of these places are cities, towns, and villages, with a total population of 50,500. The following table gives the population of the manufacturing places using water-power, from the source down:

WISCONSIN.			ILLINOIS.		
Place.	Distance from source of river.	Population in 1880.	Place.	Distance from source of river.	Population in 1880.
	Miles.			*Miles.*	
Hustisford	35	488	Rockton	135	949
Watertown	62	7,883	Rockford	153	13,129
Jefferson	80	2,115	Oregon	179	1,088
Janesville	115	9,018	Dixon	202	3,658
Beloit	131	4,790	Sterling	215	5,087
			Rock Falls	215	894
			Lyndon	234	557
			Milan	284	845

The chief points of developed water-power in Illinois are Rockford, Sterling, and Rock Falls; and in Wisconsin, Janesville, Beloit, and Watertown.

The census statistics show a total utilization of water-power on the river of somewhat more than 7,230 horse-power, by 130 separate establishments, of which 83 are in Illinois and 47 in Wisconsin. In Wisconsin over half the establishments are flouring-and grist-mills, while in Illinois there is more general manufacturing, the natural outgrowth of the requirements of a more numerous population.

Business.	NUMBER OF ESTABLISHMENTS.	
	Wisconsin.	Illinois.
Flouring- and grist-mills	26	21
Saw-mills	1	1
Paper-mills	2	7
Agricultural implements	2	14
Machine-shops and founderies	2	14
Woolen-mills	4	1

The remaining establishments are devoted to various other industries.

The existence of only two saw-mills on the river, and those small ones, shows that lumbering is a business foreign to this drainage basin. The southern limit of the pine belt is many miles north of the sources of the Rock, and these mills are probably used to satisfy a local demand for hardwood lumber.

Geology.—The Rock River basin may be said to belong to a different geological horizon from all the rivers north of it in Wisconsin. Although most of the surface is entirely covered with a great blanket of drift, as is more or less the case with the other streams, yet it is noticed, that the Rock river does not rise in the old Archæan region or on the Potsdam sandstone, but its sources are determined by the great overlying ledge of Lower Magnesian limestone, which, presenting its steep front to the north, turns the waters of the Wisconsin river west.

From this shelf the river flows southwest, following approximately the line of strike of the rock strata; hence, perhaps, its gradual westward curve, and its running through almost its entire course in the region of outcrop of the Trenton limestones.

Continuation of Green Bay valley.—The Green Bay valley, along which the lower Fox river flows, has been mentioned in describing that river. It runs southwest along the Trenton limestone, with a gradual slope westward, and on the east a steep bluff formed of soft Cincinnati shales, with hard overlying Niagara limestone.

Reaching the summit at the head of lake Winnebago, this valley continues straight on in a southwest direction, with its abrupt eastern ridge unchanged, and forms the valley of the Rock river, until the ridge gradually sinks beneath the thick accumulation of drift, and finally disappears in the southern tier of counties of Wisconsin. The opinion expressed in the *Geological Report of Wisconsin*, from which these facts are mainly gleaned, is that while the valleys of the two rivers existed previous to the Glacial age, yet they were deepened, especially the Green Bay valley, by a glacier, which ground its way through the basin of lake Winnebago, and over into the Rock valley, where it spread out to the west.

As the tendency of the lake Winnebago drainage in flowing northeast is to run close to the eastern barrier of the valley, so is it with the Rock river in flowing southwest. The dip of the strata, where not prevented by the drift, crowds the channel of drainage against the ridge.

The course of the river above Watertown is comparatively near the eastern limit of the valley, but about 10 miles above Watertown accumulations of drift have turned it from south to northwest, and finally southwest again, away from the eastern line of water-shed. The channel of the river is partly in the drift and partly in the rock, where it has succeeded in cutting through the former.

Lake Horicon, which existed until 1868, although a body of water formed by an artificial dam, yet occupied the site of an ancient lake, caused by the body of drift, which formed a natural barrier to the passage of the water. Gradually this was eroded and the lake drained, probably by the same passage which now forms the channel of the river past the village of Horicon. A dam near there, 200 feet long, would raise the water 10 feet, and restore the old lake to a certain extent.

Effect of the rock strata on the powers.—A few miles above Fort Atkinson, which is about 85 miles from the source, the river leaves the Trenton, and runs in the Saint Peter sandstone down to the state line, where it again passes upon the Trenton limestone. The result is important in its bearing upon the water-powers. The power at Watertown has fine limestone bed and banks; the powers below, in the sandstone section, so far as was ascertained, have gravel as a foundation for dams, and more or less trouble has been experienced from their instability; in Illinois hard rock is again met, and a superior bedding for dams. In places, however, the limestone is covered with drift and loose material.

There appears to have been some disturbance of the rock strata in northern Illinois, elevating them so that there is an isolated section of the Rock river, from some distance above Oregon to Grand Detour, a space of about 15 miles, in which the river runs in the Saint Peter sandstone, striking the Trenton formation again near Dixon. At that place limestone forms the left bank, but slopes so rapidly below the gravel-bed of the river as to be of no service in the construction of the dam.

In the lower section of the river the Niagara limestone appears in the bluffs along the valley, and this must form the limestone bed over which the river flows near its mouth, for the *Illinois State Geological Report* represents it as emptying into the Mississippi from the overlying Hamilton group. The extensive series of the sub Carboniferous appears to be entirely wanting in the valley, as the coal measures rest upon the Hamilton, and finally disappear from the Niagara. It is to these coal measures that the seam of coal, and soft, ferruginous sandstone found on the river at Milan and above are probably due.

It will be seen from the short account given that the course of the river is practically over the limestone strata, and to this fact is due one of its important features. Unlike the Wisconsin, Chippewa, Black, etc., which flow over geological regions of widely different character, the Rock river runs on a base of comparatively uniform hardness. There is an Archæan section of hard crystalline rock furnishing fine water-power, and then a region near the mouth where the bed is over the soft sandstone, which wears down to a uniform slope and affords few, if any, sites for water-power; but from source to mouth there are rapids either directly upon the hard limestone, or due more or less remotely to it, and many available sites, the last one within 2.5 miles of the Mississippi.

The western extension of the Rock River basin in Wisconsin, drained by the upper waters of its tributary, the Pecatonica, lies within the limits of the driftless area, described on a previous page, and the valleys occupied by the streams are not filled with drift, as is so characteristic of the rest of the basin.

Fall of the river.—The sources of the Rock river are about 876 feet, and the mouth is 536 feet, above sea-level, making the total descent about 340 feet. The average slope is 1.2 foot per mile. The most rapid section is in Wisconsin, from the mouth of the Catfish down to the Pecatonica river, where for 30 miles the average slope is 1.9 foot per mile, and next, from Oregon to Sterling and Rock falls, in which distance of 36 miles the average slope is 1.31 foot per mile. Locally there are more rapid descents than these.

The figures show that there is a rather uniform distribution of the descent, as mentioned in treating of the rock strata, and the variations serve to give a wave-like form to the profile, which is otherwise a curve, slightly concave downward. It is mainly at the local concentrations of the descent that the inviting water-powers are situated, and consequently that the prominent river towns are located.

Of the 340 feet of total descent, 126 feet is improved and in actual use, leaving 214 feet undeveloped. Mr. Joseph P. Frizell allows one-ninth of the descent of a fully improved river for providing the movement of the water, and using this estimate there are about 204 feet of unutilized fall *theoretically* available. A large amount of this is practically available—how much, would require an extensive survey to determine—but there are several fine sites lying idle which capitalists have had under consideration. These will be mentioned when the local descriptions are given.

Flow of the river.—There has been no regular series of measurements made of the discharge of the Rock river, and hence any estimate of the average or low flow must be more or less approximate. The most reliable data at hand are the result of a survey at Milan, near the mouth, and by a careful gauging the low-water flow was determined to be 3,932 cubic feet per second.

In the tables giving the flow of the tributaries of the Mississippi, the ordinary low flow of the Rock is taken to be 3,900 cubic feet per second, and the average yearly flow 9,944 cubic feet per second. These amounts agree well in the comparison with the other streams. The average yearly flow is 35 per cent. of the annual precipitation, and the ordinary low flow is about 0.36 cubic foot per second per square mile.

It will be noticed that the flow according to these estimates is nearly as great, relatively to the areas drained, as in the case of the "high-flow" rivers of Wisconsin. At first thought this would seem impossible, for the extensive tamarack and cedar swamps of northern Wisconsin are wanting in the basin of the Rock, and the surface is not so generally wooded as is the case farther north; but taking the average for the basin, the annual rainfall is from 2 to 5 inches greater, and there is altogether a large amount of woodland, while swamps are by no means rare. The region of old lake Horicon is very swampy, and the tract drained by the Green river abounds in low, swampy ground.

There are some ten lakes represented on the maps as tributary to the Rock river. These are in Wisconsin, and have a total area of 80 square miles. The largest is lake Koshkonong, about 23 square miles in extent, and then the two beautiful lakes Mendota and Monona, adjacent to Madison, the capital of the state, and having a combined area of about the same amount. Lake Horicon, when it existed, had an area of about 50 square miles, but is now drained down to a marsh and mud lake. Mention should also be made of Beaver Dam lake, about 7 miles long and three-quarters of a mile wide, formed by an artificial dam. The four Madison lakes drain into the Catfish. Beaver Dam lake is tributary to Beaver Dam river, and so to the Crawfish river. Lake Koshkonong is an expansion of the Rock river, about 10 miles long and 2 miles wide, with its foot 6 miles above the mouth of Catfish river.

These lakes exert an important effect upon the flow of the main river, especially lake Koshkonong, which has a dam at its outlet and is controlled in the interests of the water-powers below. To them is very largely due the maintenance of flow in dry and severely cold seasons.

Artificial reservoirs.—There is no physical difficulty in the way of greatly increasing the steadiness of the river by means of storage in Wisconsin, and this region has been considered in connection with river basins northward for an application of the reservoir system. The manufacturers are desirous that the government should include the river among the reservoir streams of the upper Mississippi, and point to the old basin of lake Horicon as an excellent reservoir site.

Mr. Joseph P. Frizell, assistant engineer to Major Charles J. Allen, stationed at Saint Paul in charge of the reservoir system, has made calculations with reference to the practicability of this scheme, and arrives at conclusions adverse to the undertaking of the work by the United States.

Assuming that a complete system of reservoirs were established in the basin in Wisconsin, and that all the flow from these were concentrated within one hundred days of low water in the summer, it would give a discharge of 5,787 cubic feet per second, an amount which would add appreciably to the low-water volume of the Mississippi at Rock Island, and would cause a rise of about 6 inches above low-water stage at Des Moines rapids. It is probable that such reservoirs could be constructed, but the expense would be very great for land damages, and also for the interference with the water-powers.

By renewing the dam and reforming lake Horicon there can be a discharge of 600 cubic feet per second added to the low-water discharge of the river for a period of 120 days. This would be of great value to the water-powers along the river, but would be of no practical value in the Mississippi below Rock Island, where the extreme low-water flow is 19,000 cubic feet per second.

A dam 200 feet long would raise the water 10 feet high, and the expense would be very little, but Mr. Frizell estimates that the land damages would probably amount to from $200,000 to $300,000.

It is very easy to see that the reservoir system, so far as the government promotes it, must be limited in its application to the wild lands of northern Wisconsin and Minnesota, at least until navigation upon the side streams is to be considered; and with regard to the Rock river, it is pretty safe to say that whatever is done further in the way of impounding the surplus water will be done for and by the growing water-power interests along the stream.

Lake Koshkonong.—The only body of water now controlled in the interests of the manufacturers is lake Koshkonong. There is a dam at Indian ford, 4 miles below the real foot of the lake. The total cost of the dam, land damages, etc., was $30,000, and was borne by the following water-powers in the proportions given: Janesville, 29.5 per cent.; Rockton, 16 per cent.; Beloit, 29.5 per cent.; Rockford, 25 per cent.

The lake can be drawn down 5 feet, through 40 feet of gate opening. The aim is to keep the lake full until low water in the river. In the lowest water there has not been taken from it an amount greater than 15 per cent. of the corresponding volume of the river, according to account. Ordinarily the supply is sufficient to last through the low water, but in the winter of 1880–'81 there was a steady draught upon it from September to January, and the lake was drained very low. For five years previously there had been no serious difficulty from low water.

The capacity of the lake could be very largely increased, and Mr. Frizell states that "there is no physical obstacle to the erection of a dam 20 feet high, but it would involve very heavy damages, greatly extending the area of the lake, and flowing out mill privileges above".

The expense of increasing upon an extensive scale the storage capacity of Rock River basin is seen to be very great, and doubtless deters the manufacturers from an extensive system of improvement. This expense will increase with the value of land, but the manufacturing interests are also destined to develop, and as the necessity is more and more felt for a greater stability of flow, there is reason to believe that the capital invested will warrant the extensive storage of water, perhaps such as is found upon some of New England's manufacturing streams.

There is this disadvantage: that the surface is not mountainous, and hence the tendency is for reservoirs to be broad and shallow instead of deep; thus extensive tracts are overflowed, and generally these will consist of valuable land.

Table of fall, drainage areas, flow, etc., of the Rock river.

Locality.	Distance from source.	Distance from preceding station.	Fall from source.	Fall from preceding station.	Drainage area above station.	Flow per second past station in cubic feet.		Theoretical power under 10 feet head.	
						Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Miles.*	*Feet.*	*Feet.*	*Sq. miles.*	*Cubic feet.*	*Cubic feet.*	*H. P.*	*H. P.*
Utmost source									
Former outlet of lake Horicon	25	25	20	20	497	179	450	203	511
Above mouth of Crawfish river	80	55	93	73	1,102	397	998	450	1,132
Mouth of Crawfish river	80	0	93	0	1,899	684	1,720	776	1,951
Fort Atkinson	87	7	97	4	2,290	824	2,075	935	2,354
Above mouth of Catfish river	105	18	108	11	2,645	952	2,396	1,080	2,718
Mouth of Catfish river	105	0	108	0	3,175	1,143	2,877	1,297	3,264
Above mouth of Pecatonica river	135	30	165	37	3,795	1,366	3,438	1,550	3,900
Mouth of Pecatonica river	135	0	165	0	6,403	2,305	5,801	2,615	6,581
Above mouth of Kishwaukee river	160	25	189	24	6,703	2,413	6,073	2,738	6,890
Mouth of Kishwaukee river	160	0	189	0	7,970	2,869	7,221	3,255	8,192
Mouth of Leaf river	173	13	212	23	8,476	3,051	7,679	3,461	8,712
Above mouth of Elkhorn creek	221	48	280	68	8,915	3,209	8,077	3,641	9,163
Mouth of Elkhorn creek	221	0	280	0	9,175	3,303	8,313	3,747	9,431
Above mouth of Rock creek	250	29	307	27	9,330	3,359	8,453	3,811	9,590
Mouth of Rock creek	250	0	307	0	9,543	3,435	8,646	3,897	9,809
Above mouth of Green river	274	24	325	18	9,680	3,485	8,770	3,954	9,950
Mouth of Green river	274	0	325	0	10,811	3,892	9,795	4,415	11,112
Mouth of Rock river	286	12	340	15	10,973	3,950	9,942	4,481	11,279

Table of the tributaries of the Rock river.

River.	Length.	Drainage area.	Discharge per second.		Theoretical power under 10 feet head.	
			Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Sq. miles.*	*Cubic feet.*	*Cubic feet.*	*H. P.*	*H. P.*
Crawfish river	60	798	287	723	326	820
Catfish river	40	530	191	480	217	545
Pecatonica river	140	2,608	939	2,363	1,065	2,681
Kishwaukee river	50	1,266	456	1,147	517	1,301
Elkhorn creek	40	261	94	236	107	268
Rock creek	45	213	77	193	87	219
Green river	80	1,131	407	1,025	462	1,163

DESCRIPTION OF THE WATER-POWERS.

Taking the water-powers in their order of occurrence from the source to the Mississippi river, the characteristic features of each are as follows, naming also known undeveloped sites:

From the source to Watertown.—On a branch of the river which flows from the west in Washington county, there is a small saw-mill using about 8 horse-power under a head of 12 feet, but with that exception there is no utilized power which can be considered to be situated on the Rock river until Hustisford is reached, 10 miles below the village of Horicon, which is at the old outlet of lake Horicon.

Hustisford.—At Hustisford there are two grist-mills and a saw-mill. In the census returns the grist-mills are rated as using 65 and 90 horse-power under heads of 8 and 7 feet, respectively, and the saw-mill is rated as using 35 horse-power under a head of 13 feet. These are probably greater than the true amounts, as the grist-mills have only two or three runs each.

Second power.—The next utilized power is 22 miles below Hustisford and 5 miles above Watertown, where there is a mill with three runs of stones under a head of 4 to 6 feet, and at Watertown a small saw-mill, which, however, does not appear in the census returns.

Third power.—The next and last power used above Watertown is 1 mile above that place, and is taken by a four-run mill, working under a head of 6 or 7 feet, and probably using 50 or 60 horse-power. All these powers and the remaining three above lake Koshkonong have the disadvantage not experienced by the other water-powers below, of having no artificially-regulated reservoir, and hence must depend largely upon the natural storage of the Horicon swamp for the maintenance of the flow.

The total fall from the village of Horicon to Watertown is 59 feet, of which only 25 feet is in use; for the remaining 34 feet there are probably some sites at which it would be feasible to utilize part, although the river is not considered by manufacturers to offer good sites within this distance.

Unutilized power of lake Horicon.—At the village of Horicon is the now unutilized power which could be formed by throwing a short dam across and renewing lake Horicon.

Mention has been made of the fact that a dam was built there in 1842 and removed in 1868, owing to a decision against the owners, the Merchants' Union Manufacturing Company, because of damages to private land-owners. It is claimed by some interested in the water-powers below, that while this was the ostensible reason of the removal, the true cause was the interest in favor of a land-reclaiming scheme. Be this as it may, the dam gave a head of 9.5 feet of water, and power for some mills which formed the nucleus for the village. With the large reservoir to draw from, the power must have been very steady and have amounted to well toward 500 horse-power.

There is nothing to prevent the renewal of this power, except the large expense resulting from land damages by raising the level of the lake. It would probably be too great for this single power to carry, but if the lake is ever used as a reservoir by the manufacturers along the river, the value of the power here created would be an item in the financial calculation of the project. Mr. Joseph P. Frizell, in his report already alluded to, states that the Merchants' Union Manufacturing Company still owns the greater part of the land that would be overflowed, and assumes in his calculations that this company would release the land in consideration of the water-power that would be created.

Mr. Frizell's estimate of from $200,000 to $300,000 for the land damages is based on a raising of the lake-level 10 feet. This would require a dam not over 200 feet long.

Watertown.—This town, of 7,883 inhabitants, is situated just below the sharp bend in the river from northwest to south. Three lines of railroad connect at this place; the Chicago and Northwestern runs north and south along the river, and there are two branches of the Chicago, Milwaukee and Saint Paul, one passing east and west through Milwaukee and Madison, and the other running northwest from Watertown through Portage City on the Wisconsin, and so to Saint Paul.

The river is 150 or 200 feet wide, with banks sloping gently back to a height of from 10 to 20 feet. It has not worn so deeply into the drift as has been done farther south, but nevertheless the rock has been reached in places, and where the dam is located the bed and banks consist of hard Trenton limestone. The dam is 10 feet high and about 150 feet long, built of framed oak timber. It runs straight across the river.

There are six establishments using the power at Watertown, all under 10 feet head of water. As nearly as can be ascertained from statements made at the place, the powers used are these:

Right or west bank.—Flouring-mill, 110 horse-power; woolen-mill, 40 horse-power; sash factory, 35 horse-power.

Left or east bank.—Custom mill, 44 horse-power; foundery, 20 horse-power; flouring-mill, 150 horse-power.

This makes a total of 399 horse-power, and represents, practically, the total available power of the river, so that without increasing the head there is no more power available at this point, unless reservoirs are created above for regulating the flow.

The following points were gleaned from a conversation with one of the manufacturers: The full power is obtained generally for eight months of the year, and when the fall rains have been heavy there is no difficulty for nine months of the year. In dry times the river is very small, and the mills are largely run by steam-power. When lake Horicon existed they had a good steady power all the year through.

Watertown to Janesville.—The total descent from Watertown to the upper pond at Janesville is 28 feet, and, as there are already three dams taking 17 feet of this, it is evident that the available power remaining undeveloped cannot be very great, and it is stated that none exists.

The first utilized power is 1.5 mile below Watertown, and is taken by a mill with five small "pony" runs, under 6 feet head of water. There is, of course, a large amount of unutilized power at this place.

Jefferson.—The next power is at Jefferson, just above the mouth of the Crawfish river. The slope of the banks is much like that at Watertown, but the river is at least 100 feet wider. The dam is about 225 feet long, and the head is not over 4 or 5 feet.

There is a flouring-mill of four runs of stones, taking 65 horse-power, and a woolen-mill taking 20 horse-power; both are on the right bank of the river. According to the estimates in the table, the theoretical power under the ordinary low flow is 225 horse-power, and there must be considerable power unused.

Outlet of lake Koshkonong.—The dam at the foot of lake Koshkonong, controlled by the manufacturers below for regulating the flow of the river, affords an available head of 6 feet.

There are at present only two small grist-mills using the power afforded by lake Koshkonong, but there has been some consideration by the manufacturers of renting the power.

With a head of 6 feet the theoretical power, under a natural condition of the river, would be from 600 to 700 horse-power, with the ordinary low flow, but owing to the flow from lake Koshkonong being controlled entirely in the interests of the water-powers below the mouth of the Catfish river, there might be a large variation in the amount of power obtainable.

Janesville.—This is a town of considerable importance, with a population of 9,018. There is direct connection with Chicago by the line of the Chicago and Northwestern railroad, running north through Watertown, and branch lines connect with the roads running to Madison, and so west.

There are two water-power levels which may be considered to be situated at Janesville—one in the city, and one about a mile and a half below, in the suburbs.

The upper level.—The upper level is the more fully developed of the two, and is situated in the heart of the business portion of the town. The dam extends straight across the river, just below the crossing of the Chicago and Northwestern railroad, and on the right bank a race runs down-stream 1,500 or 2,000 feet, with eight establishments upon it. On the left bank there is a short race, with only two establishments using water-power. The head used at this level averages 7.5 feet.

The power is owned by the manufacturers, who are not consolidated into a hydraulic company, although there is a desire to bring this to pass, as it would enable them to control the power to greater advantage. Mutual agreements are made as to assessments for repairs, division of the power, etc. When the original improvement was made the power was estimated to be 13,309 "inches" of water under a head of 4 feet, which was the original height of the dam. The power, as estimated on this basis, is divided among the different establishments in the proportions given in the following table. The mills are given in the order of their occurrence below the dam:

Establishment.	Number of "inches" of water owned.	Number of cubic feet per second.	Theoretical horse-power under 7.5 feet head.
Right, or west bank.			
Flouring-mill	2,200	245	209
Cotton factory	4,350	485	413
Flouring-mill	1,700	189	161
Sash factory	459	51	44
Cabinet-shop	400	45	38
Grist-mill	600	67	57
Flouring-mill	450	50	43
Flouring-mill	2,100	234	199
Left, or east bank.			
Feed-mill	450	50	43
Foundery and machine-shop	600	67	57

The right is owned to raise the head to 8 feet. The total power owned under the 7.5 feet of average head is 1,264 theoretical horse-power. The tables give a power, with the ordinary low flow under this head, of about 975 theoretical horse-power. It is evident that the power is all taken up by the existing manufactories. In a low-water year, except extreme ones, they can run at full capacity for nine months of the year, and sometimes for eleven months. In wet years they are not troubled by low water. The wheels are never stopped by back-water, although it sometimes diminishes the power. The dam is about 300 feet long, and consisted originally of brush and timber resting on the gravel-bed of the river. It has been much repaired, and when seen, in the spring of 1881, was in an insecure condition.(*a*)

The lower level.—At the lower level there are four establishments using the power, which has not been so completely developed as that in the town. A race extends down the right bank 1,500 or 2,000 feet below the dam. The head at the dam is about 5.75 feet, and at the end of the race it is 8 feet. With the latter head the power with the ordinary low flow is about 1,000 theoretical horse-power.

The left bank is steep and bluffy, and the only establishment located upon it is a flouring-mill directly at the dam, taking 225 horse-power under a head of 5.75 feet. The right bank stretches away in a broad flat, affording fine opportunities for utilizing the power. At the lower part of the race on this side are a small wheel for pumping water into the water-tank of the railroad, a custom-mill taking about 30 horse-power, and a woolen-mill taking about 40 horse-power under 8 feet head.

Because the power is not fully used there is a large amount of water wasted in the mills, which have old-fashioned wheels. About one-third of the available power is actually employed, and there is plenty of room for the use of the remainder.

The dam was partly carried out in the spring of 1881, but it was the intention to rebuild it. There is at present much contention and litigation in connection with the ownership of the power.

From the lower level at Janesville down to Beloit, a distance of 15 miles, there is a fall of only from 10 to 13 feet, and no available power offers for improvement.

Beloit.—Beloit is situated in Wisconsin, on the east bank of the Rock river, just where it crosses the state line into Illinois. It is a town of 4,790 inhabitants, doing a large manufacturing business, and takes a prominent place

a The dam at the upper level was carried out by the high water of April, 1882.

among the cities of that region. Two lines of railroad intersect at Beloit—the Chicago and Northwestern, running northwest, and the Chicago, Milwaukee and Saint Paul, running southwest. These furnish connection with numerous other lines of road.

The city is on both sides of the river, but the main part of the manufacturing is done upon the west side. This is due to the nature of the topography. In the vicinity of Beloit the river varies usually from 200 to 300 feet in width, but in some places expands to a greater breadth than this. The river-banks are generally comparatively low, but back from the river are the bluffs, sloping back into the general level of the surrounding country.

At the town the river runs near the east bluff, and the bank is high and steep, making it a difficult matter to utilize the power; while on the west the bank is comparatively low, and the land stretches away level for a considerable distance to the rise which bounds the valley.

The dam extends straight across the river just above the town, and a race runs along the west bank for a considerable distance below it, supplying ten establishments with power.

On the east bank there is at present only one establishment, a paper-mill, situated at the dam in a depression of the bank; but there was, in the spring of 1881, a building in process of erection just below it for a manufactory, which was expected to use some of the power.

All the power is owned, and practically all is used, by the manufacturers, who form a chartered company, and whenever expenses are incurred for repairs or other necessary matters, assessments are made upon the members in proportion to the interests held by them.

The first improvement was made in 1842, by the same person who developed the power at the upper level at Janesville, and, as in that case, the original dam was 4 feet high, and the power was estimated to be 13,333 "inches" of water under a head of 4 feet. The head of water now used (spring of 1881) varies from 6 to 8 feet, but averages 7 feet. The charter of the company allows a head of 8 feet, and all damages for flowage due to a head of 7 feet have been paid, as well as part of those for an 8-foot head.

Under the old system of estimating the power on a basis of 13,333 "inches" of water, the mills were drawing more than their portion of the water, because of taking it at a head of 7 feet instead of 4 feet. On this account the power was divided into 800 "shares", each share being equivalent to $16\frac{2}{3}$ "inches" of water under a head of 4 feet, and these shares were distributed among the members of the company in proportion to the number of "inches" held by each under the old contract. Now, one share means one eight-hundredth of the flow of the river, whatever that may be. There were some who held "preferred claims", that is, first-right claims, but by these being in part relinquished, and in part bought off, all the powers were placed upon an equal footing.

There are eleven separate establishments, but the ownership of the power is divided among eight different firms and individuals. There is a paper-manufacturing company owning nearly one-half the entire power, and it has a paper-mill on the west bank, besides the one upon the east bank of the river. This company leases 500 "inches" of water (old system) to a machine-knife works, and 340 inches to a foundery.

The following table gives the manufactories in the order of their occurrence on the race along the west bank, and the power owned or controlled by each interest:

Establishment.	"Inches" of water under 4 feet head.	Number of shares owned.
Paper-manufacturing company	6,650	399
Strawboard-paper company	2,000	120
Machine-knife works (*a*)	.....	.....
Foundery (*b*)	.....	.....
Wood-working shop	400	24
Scale manufactory	$183\frac{1}{3}$	11
Flouring-mill	1,100	66
Flouring-mill	1,500	90
Flouring-mill	500	30
Iron-works	1,000	60

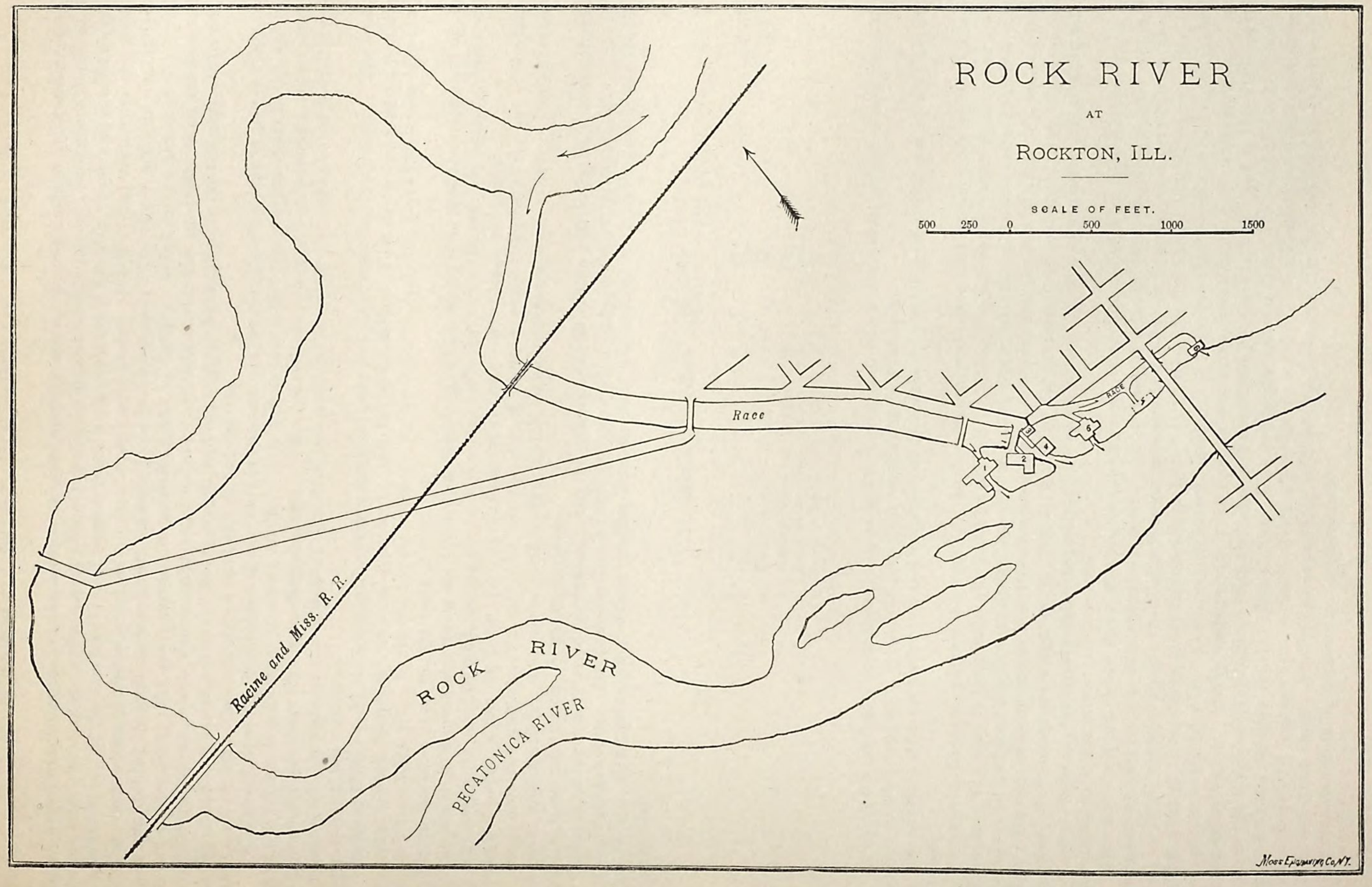
a Leases 30 shares from the paper-manufacturing company.
b Leases 20.4 shares from the paper-manufacturing company.

The paper-mill upon the east side of the river has four Houston turbines under a head of 6 feet, and their total power is rated at 113 horse-power.

There is no difficulty from low water except in unusually dry seasons or cold winters. However, at times economy has to be practiced in the use of the water. The influence of lake Koshkonong is of great value here, as well as at the adjoining powers.

Ordinarily there is no special annoyance from back-water, as the usual rise is only 4 feet, but in the spring of 1881 the water rose 7 feet, and interfered seriously with the manufactories along the race.

The dam is constructed of riprap with a wooden apron on the lower side, and gives a head of about 6 feet, backing the water 5 miles up-stream. The bed of the river is gravel. The dam ran out 250 feet from the east bank,


ROCK RIVER
AT
ROCKTON, ILL.
SCALE OF FEET.
500 250 0 500 1000 1500
Race
Race
Racine and Miss. R. R.
ROCK RIVER
PECATONICA RIVER
Moss Engraving Co. N.Y.

and connected with an embankment projecting from the opposite shore. During the high water of the spring of 1881 and the river ran over the embankment behind the abutment, and washed it away, with about 30 feet of the west end of the dam. If the dam had been of wooden frame-work probably it would have all been carried away, but its peculiar construction of riprap acted as a heavy stone embankment. When visited soon after the accident the water was rushing through the break with immense force, in a mass some 20 feet deep, and was constantly wearing the bed of the river. The plan pursued in rebuilding was to throw in heavy square blocks of stone and great quantities of riprap, which were carried some distance by the current, but gradually filled the opening. The overflow was to be increased to 292 feet in length, and the average head raised to the full amount allowed by the charter, viz., 8 feet. This will give a head of 7 feet at the dam.

From Beloit down to the Rockton dam, where is encountered the next developed water-power, there is a total fall of 8 or 10 feet in a distance of about 3 miles. It is practicable to develop a water-power in this distance, but no very good place offers for a manufacturing site. When the railroad company was building its line up the valley, it made an offer to some of the citizens of Beloit of the authority to locate the road if they would improve the power, but nothing was done.

Rockton, Illinois.—At Rockton is the first improved power met after crossing into Illinois. The river makes an extensive bend from south to west, then south, and finally southeast. Just below the western portion of the bend the Pecatonica river, by far the largest tributary, enters from the west, and about half a mile below its mouth is situated Rockton, upon the left bank of the river.

The power is obtained by means of a race 4,325 feet long, which starts from near the upper end of the bend and runs across the neck of land, ending at the river bank 1,000 feet above the highway bridge which crosses the river at the town. From its lower end a smaller race runs down-stream 1,250 feet farther.

There are six establishments using the water-power, of which four are situated at the end of the large race, between it and the river. The power is all owned by the manufacturers, and all in use; if there were any more available, it would be soon bought up by them.

There is no regular water-power company, but the owners have formed an association as a means of preserving their common interests. The power is divided into 96 "shares", held in the following proportions by the different manufactories, given in the order of their position down-stream. The numbers refer to the positions of the buildings upon the map:

No.	Establishment.	Shares.	Theoretical horse-power.
1	Paper-mill	40	560
2	Paper-mill	12	168
3	Machine-shop	2	28
4	Flouring-mill	10	140
5	Paper-mill	28	392
6	Flouring-mill	4	48

At the point marked 7 upon the map there was a flouring-mill which was burnt, and the shares, 12 in number, were sold to the paper-mill, No. 1, bringing their amount up to 40 shares.

The average head on the wheels is 8 feet, and this is obtained by cutting off a distance by the river of about 2.5 miles.

The head of the race is above the mouth of the Pecatonica, and hence that stream adds nothing to the power at Rockton. The flow is practically the same as at Beloit. Using the estimated power at Beloit as a basis for calculation, we find that the flow on which that power was originally calculated is 1,486 cubic feet per second (the ordinary low flow as estimated in the tables for the river is 1,366 cubic feet per second), and this, under a head of 8 feet, gives 1,349 theoretical horse-power. Dividing this by 96, the amount of a share at Rockton at an ordinary low stage must be approximately 14 horse power. The power owned by each manufactory, as given in the table, is calculated with this factor.

Low water does not create any difficulty, except in years of very low water, and lake Koshkonong is looked upon as adding very much to the value of the power. The detriment to the power is the back-water, which is mainly caused by the Pecatonica river. Ordinarily there is more or less trouble each spring, and sometimes in the fall.

The head of water varies in ordinary seasons from 7 to 10 feet. In the spring of 1881 occurred the highest water for at least thirty years. The river rose 10 feet, running over the race embankment and making one continuous sheet of water with it. Thirty years previously to this the water rose to within 9 inches of this height.

From the Rockton level down to Rockford, the next developed power, is 18 miles, and in this distance there is a total fall to the Rockford level of 10 or 11 feet. It is feasible to utilize this fall at a point above Rockford, where a head of nearly 10 feet can be obtained. With the ordinary low flow, a head of 10 feet would give from 2,000 to 2,500 theoretical horse-power. Persons residing in Rockford have had the development of this power under consideration, but nothing decisive has yet been done.

Rockford.—This is the principal manufacturing center on the river, and as it has a population of 13,129 it ranks among the large towns of northern Illinois. The location is upon the west bank. A line of the Chicago and Northwestern railroad runs northwest through the town from Chicago, another line runs northeast from Rockford to Kenosha on lake Michigan, and a short line runs south, crossing the Chicago, Milwaukee and Saint Paul, and connecting at Flagg Centre with other branches of the Chicago and Northwestern. These roads afford ready communication with all the centers of trade, and assist much in the general prosperity of the place.

To a stranger placed in the midst of the manufacturing section of Rockford the impression would be that he was surrounded by a city of manufactories. There are some thirty-two separate establishments using water-power, and these, with their many buildings, storage-sheds, etc., cover a large space. With the exception of three flouring- and grist-mills on the east bank, all the establishments using water-power are on the right, or west bank of the river, which affords the best facilities for developing the power.

The accompanying map shows the plan on which the power is improved. A curved dam, 608 feet long, of cribwork, resting on a lime-rock bed, runs across the river, and from it a short race extends down 285 feet the east bank, supplying the three flouring- and grist-mills before mentioned. On the west bank a race 1,000 feet long and 85 feet wide extends down-stream at a distance of from 200 to 300 feet from the river-bank to within 300 feet of a small stream, called Kent's creek, which enters the river at that place, and from its lower end a smaller race runs up the shore of Kent's creek for 450 feet.

The wheels are situated on the river and creek sides of the two races, and the manufactories are upon both sides of the races, either directly over the wheels or communicating with them by lines of shafting or wire rope. The average head of water is 7 feet, but it averages 6 feet at the dam and 8 feet at the foot of the race.

The railroads facilitate the shipping of freight, and a side-track extends the entire length of the race on the west bank.

Division of the power.—The power is owned by a stock company, and is divided into 20,000 "parts", a "part" being a purely local unit equivalent to one-tenth of a horse-power. The power of the river is held to be 2,000 horse-power under 7 feet head of water, and each member of the company owns his power with that head of water, although the flow of water to which it entitles him may be used under a head of 6 or 8 feet. Assessments are made whenever repairs are necessary, and they average 25 cents per horse-power per annum. The president of the company is Mr. Ralph Emerson. The following table gives the amount of stock and the number of water "parts" owned by each of the nineteen members; the members of the company either use the power themselves or lease it to others, and practically all is now in use:

Name.	Number of shares of stock.	Number of water "parts".	Name.	Number of shares of stock.	Number of water "parts".
D. L. Bartlett & Bros	176	2,200	Frank C. Landers	40	500
Briggs & Enoch	40	500	J. P. Manny	32	400
J. G. Chick	224	2,800	J. Rodd	48	600
T. Derment	72	900	Rhoads, Utter & Co	128	1,600
William Dyson	32	400	R. H. Tinker	236	2,950
Emerson & Co	112	1,400	W. D. Trahern	32	400
Emerson, Talcott & Co	80	1,000	N. C. Thompson	120	1,500
A. D. Forbes	32	400	Central Furniture Company	24	300
Graham Cotton Mills	80	1,000	Isaac Utter	60	750
W. A. Knowlton	32	400			

The attempt to ascertain personally the amount of power used by each establishment was abandoned, as it was found to be impracticable. The census returns give a total of about 1,500 horse-power in actual use at Rockford, but are compiled in such a form that the amounts cannot be readily assigned to the different manufactories. These are shown in their proper locations upon the map. As before mentioned, practically all the power is now in use, and hence in dry seasons some of the mills are short of water, but they can all run nearly all the time. The Thompson Plow Works have a steam-engine which is used in very low water.

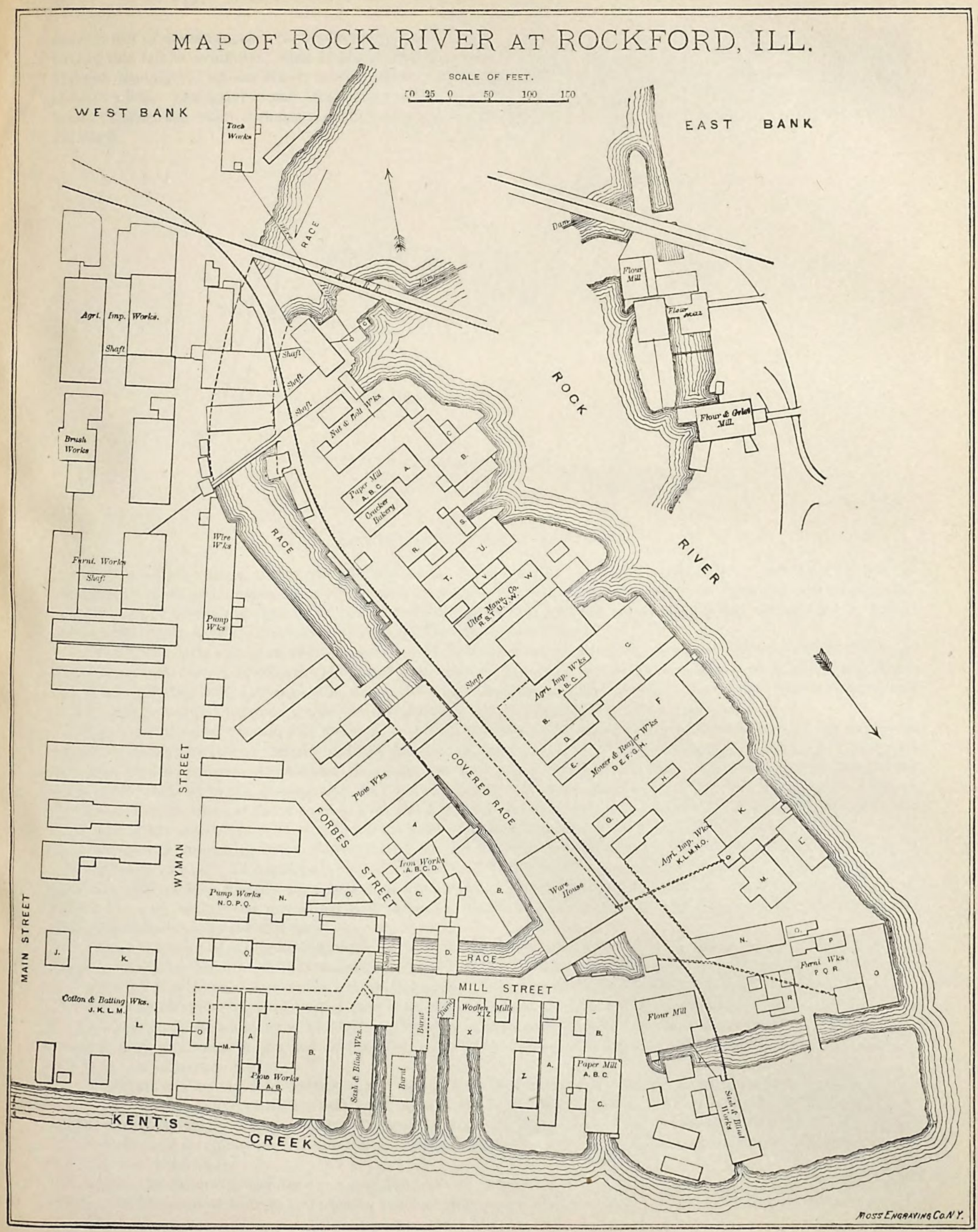
Rockford is the lowest one of the four water-powers which bore the expense of the reservoir at lake Koshkonong. The Pecatonica river makes their power less uniform than the powers above.

There is considerable fall in the river below the race, and back-water gives no trouble except in very high stages of the river.

There is very little chance of increasing the power by increasing the head, for although the river falls rapidly below the race, Kent's creek would prevent the extension of the latter; and because of the existing manufactories it would hardly be lengthened if practicable. The dam cannot well be raised to any great extent because of overflow, and, as it is, damages have had to be paid. The pond extends 12 miles up-stream, nearly to Roscoe.

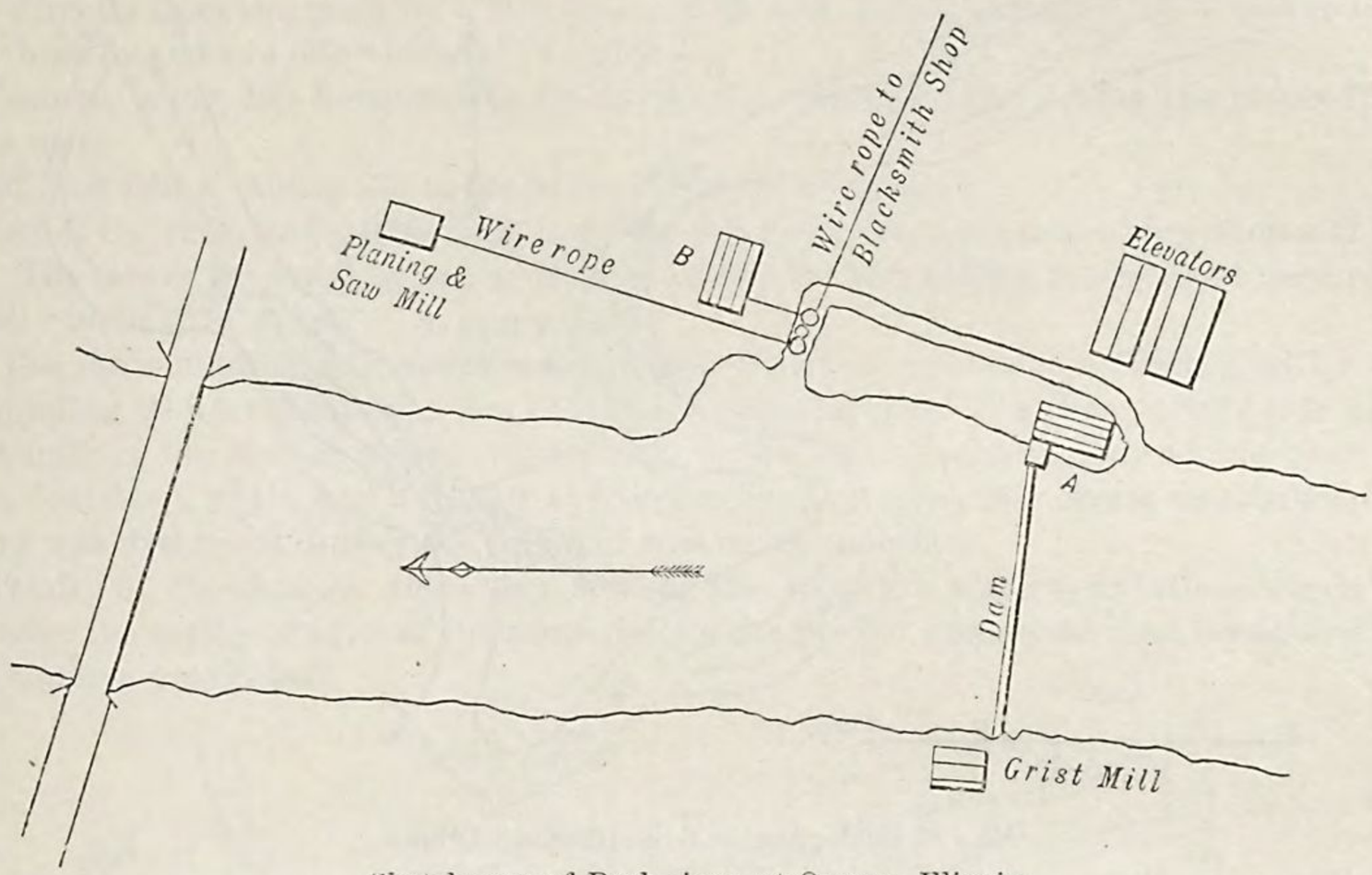
Rockford to Oregon.—From Rockford down to the next improved power, at Oregon, the distance by river is 26 miles, and the total fall from below the Rockford level to the level of the Oregon pond is from 25 to 27 feet. The Oregon pond backs up to the mouth of Leaf river, and the fall from Byron, 4 miles above, is only about 3 feet; hence

MAP OF ROCK RIVER AT ROCKFORD, ILL.



MOSS ENGRAVING CO. N.Y.

over 20 feet of descent occurs in the distance of 16 miles from Rockford to Byron. There are two points at which part of this fall is available. One is about 2 miles below Rockford, where a head of 6 or 8 feet can be obtained without flooding the wheels above, and the other is at Byron, which is at the foot of a rapid that extends up-stream about 3 miles. The water is not broken, but is swift and shallow. A dam has been proposed from which a race would conduct the water through a natural depression across a neck of land, and a head of about 6 feet would be obtained.



Sketch map of Rock river, at Oregon, Illinois.

Oregon.—This village, with 1,088 inhabitants, is situated on the west side of the river. A railroad, known as the Chicago and Iowa, crosses the river about a mile below the water-power, opposite to which the town is situated. A dam extends across the channel of the river, and a short race supplies the manufactories, which are all located on the west bank, with the exception of a grist-mill upon the east bank.

During the early spring of 1881 there were three establishments using the power on the west side of the river: an oatmeal-mill, then a blacksmith-shop and plow factory, receiving power by wire-rope transmission, and last a a saw-mill, planing-mill, and feed-mill, all in the same building and run by wire rope. There was a flouring-mill nearly completed, and between it and the oatmeal-mill were the foundations for a paper-mill.

The head of water averages 5½ feet, and it is with this head that the power is calculated. With the exception of 2,000 "inches" owned by the grist-mill on the east side of the river, the power all belonged to Henry A. Mix, and has come into the possession of his heirs, less 3,500 "inches" sold in the following way: 1,600 "inches" to the oatmeal-mill, 1,500 "inches" to the flouring-mill, and 400 "inches" to the saw- and planing-mill. Six horse-power is leased to the blacksmith-shop, at the rate of $75 for the first year and $100 per year afterward. Heretofore the water has been sold at the rate of $4 per "inch" under a head of 5½ feet, but the rate will probably be increased.

The census returns give the power in use by the different establishments as follows: Blacksmith-shop, 16 horse-power; saw-mill, 12 horse-power; two flouring- and grist-mills, 70 and 59 horse-power, respectively. The power is very reliable, as only a small part of it is in actual use, and a large amount yet remains to be disposed of. Races can very readily be run down both sides of the river when required, and the ownership of the land is arranged satisfactorily for this purpose.

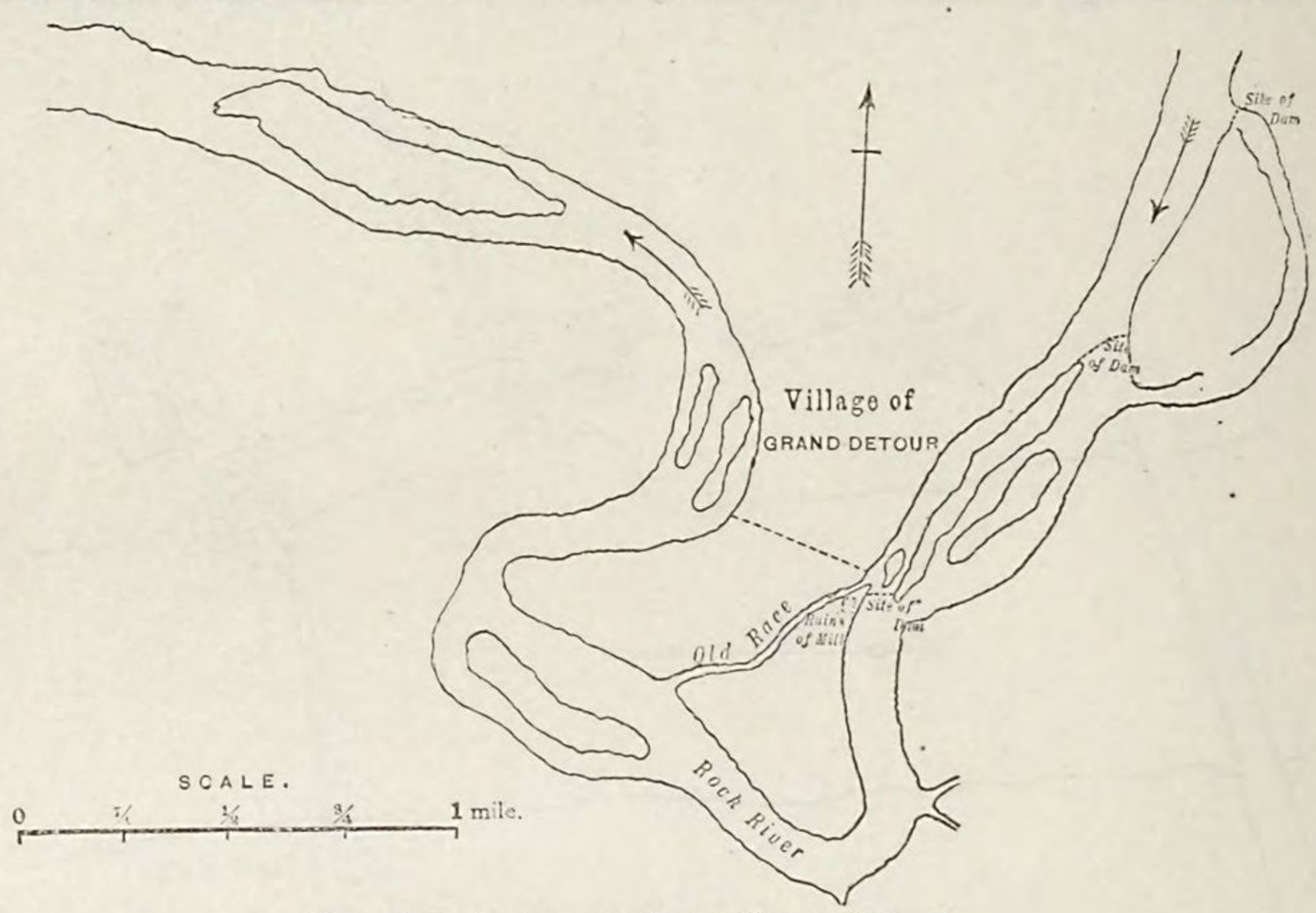
While the head of water is ordinarily 5½ feet, it has at times diminished to 4½ and even 4 feet, owing to low water. The mills have to shut down two or three days during the breaking-up of the ice, but that is practically all the delay they have. Sometimes the ice has gorged below the town and backed the water upon the wheels.

The bed of the river is of gravel, free from clay. This washes out easily, and considerable trouble has been experienced from the scouring of the bed and banks. At one time a part of the dam was carried away and a hole 40 feet deep was worn in the bed of the river. Owing to repeated fillings the bed under the dam is largely an artificial one of broken stone.

The dam was constructed by first throwing in stone until the bed was raised to within a foot of the low-water level, and then the superstructure was built upon this. It consists of courses of logs laid side by side, with their upper branches left on and the butts lying down-stream. A string-piece is laid across the butts of the logs, setting back 2 feet, and on this rests another course, about every fifth log being bolted to the stringer. Broken stone is filled in between the courses.

Oregon to Dixon—Grand Detour.—For the next 23 miles, down to Dixon, there is no developed water-power. There is a total fall of 26 feet, and about 16 feet of this occurs between Oregon and Grand Detour, 14 miles below.

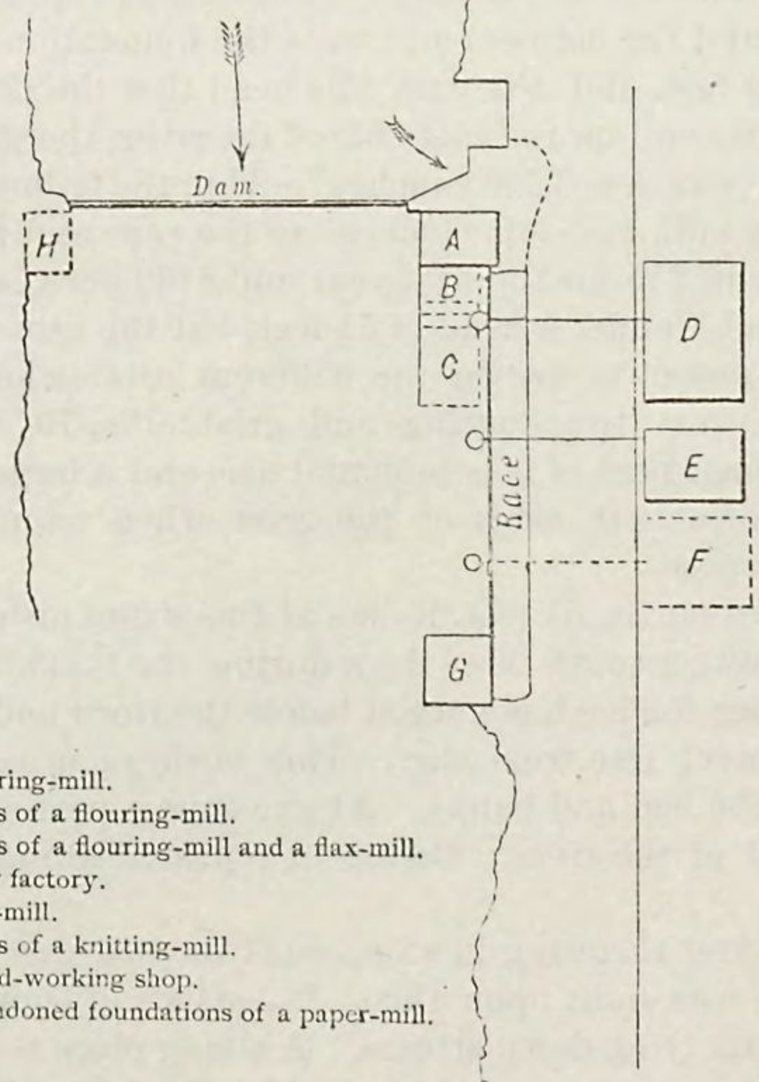
At Grand Detour is met what is probably the finest natural site for a water-power in the entire length of the river The channel makes an extensive bend of about 3 miles, and at its narrowest point the neck of land is only about 1,850 feet wide. By cutting a race across at this point a head of 8 feet can be obtained merely with a dam across one channel to the island shown in the map, while by throwing a dam entirely across the river it is claimed that a head of nearly 16 feet can be used.



Map of Rock river, at Grand Detour, Illinois.

In 1837 a dam and race were built, one or two mills started, as indicated upon the map, and the village of Grand Detour promised to be a place of importance. The location of the railroad line through Dixon diverted population, however, and now there are only 253 inhabitants. The dam was carried out by the water, the race is nearly filled up, and the mills are not used.

No other very valuable power offers between Oregon and Dixon, although it is probable that a portion of the fall below Grand Detour could be utilized.



A—Flouring-mill.
B—Ruins of a flouring-mill.
C—Ruins of a flouring-mill and a flax-mill.
D—Plow factory.
E—Flax-mill.
F—Ruins of a knitting-mill.
G—Wood-working shop.
H—Abandoned foundations of a paper-mill.

Sketch map of Rock river, at Dixon, Illinois.

Dixon.—At this town is a developed water-power affording 6.5 feet head of water. All the establishments now using the power, four in number, are located on the left bank of the river, and the wheels are supplied from a race

about 500 feet long, which extends between the river and one of the streets of the town. The dam is about 700 feet long. The owners of the power do not form a company, but co-operate in the maintenance of the dam and other hydraulic works. Only a small portion of the power is in actual use.

The manufacturing industry of the place received a severe check in April, 1880, when most of the mills were destroyed by fire. The manufactories, as they existed in the spring of 1881, were these:

1. A flouring-mill at the head of the race, which had just been rebuilt and started on the ruins of the old mill. This mill draws directly from the pond by a short race of its own, and is also entitled to power from the large race. The total power here owned is 4,000 "inches" of water.

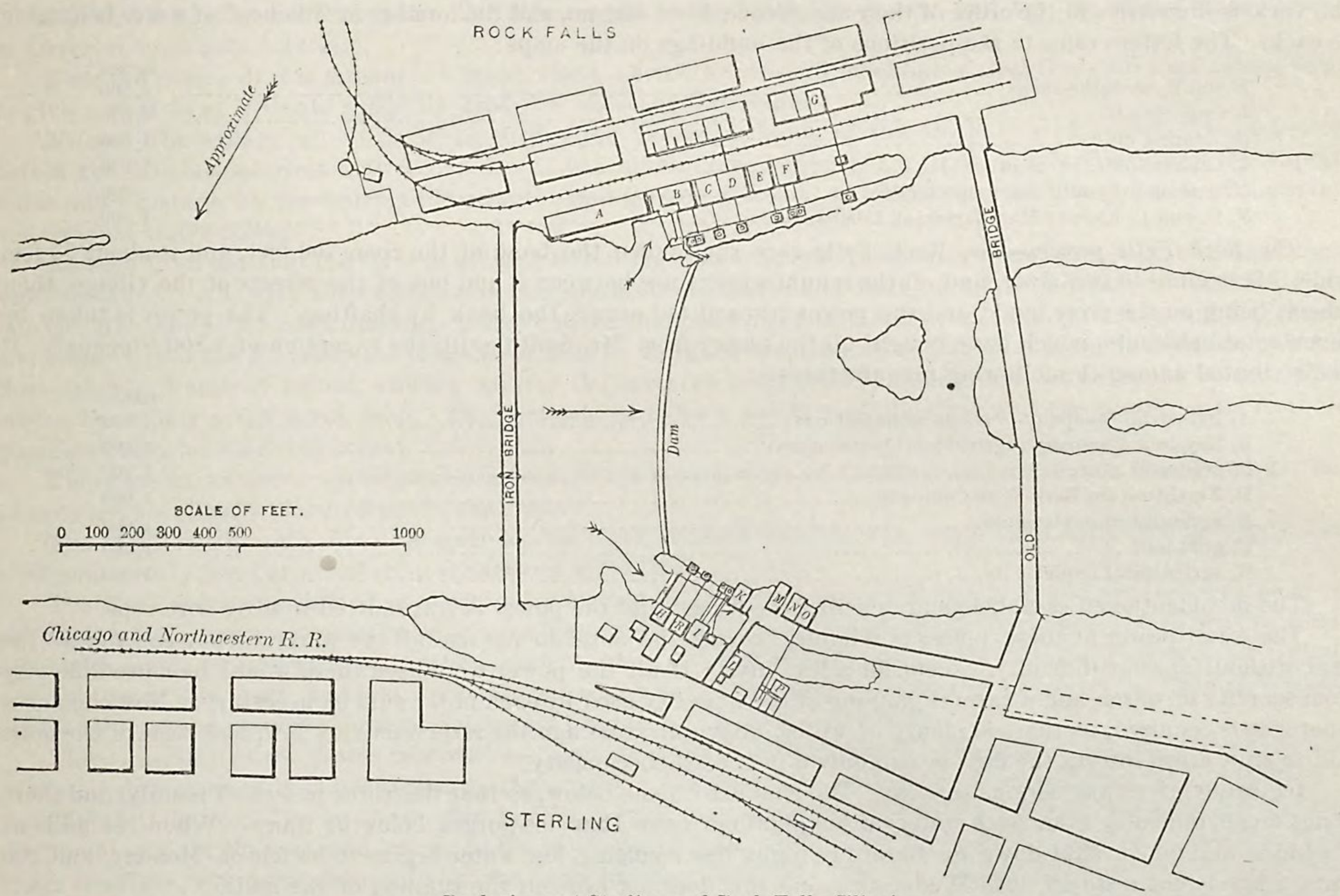
2. A plow factory, using 100 horse-power by means of a shaft running across the street from a wheel on the other side of the race.

3. A flax-mill just below taking 100 horse-power in the same manner.

4. At the foot of the race, and partly built out over the river, are a wood-working shop and a grist-mill, in the same building. The power is owned by the proprietor of the former, and he rents about one-half to the grist-mill. The total is 1,200 "inches" of water.

Just below the large flouring-mill at the head of the race are the ruins of a flouring-mill, and adjoining it are the ruins of a building which contained a flax-mill and a flouring-mill. On the opposite side of the street, below the present flax-mill, is the site of a knitting factory, which also was burnt four or five years ago. Above the plow factory is a foundery, which had a line of shafting extending along the street and transmitting the power to it. This shafting was destroyed during the fire, and was never renewed.

At the extremity of the dam on the other side of the river are some foundations which were started for a paper-mill, but after the outlay of several thousand dollars the project was abandoned because of the expense of the construction on the fine gravel bed.



Rock river, at Sterling and Rock Falls, Illinois.

Power is, of course, never lacking to the manufacturers, because of the small amount used. There are good opportunities for further utilization, and vacant spaces on the present race. There is no physical obstacle to extending the race about 500 feet farther down the river to the highway bridge, but the owner of the land is reported to hold it at so high a price as to have prevented this in the past.

The location is not the best possible one for a dam. The race is partly excavated in solid limestone, and the left bank consists of this, but it sinks rapidly beneath the bed of the river, and the dam is built upon a gravel bed. The construction of the dam is much the same as in the case of that at Oregon—courses of logs and brush weighted

with stone. The top is covered with a double layer of pine and oak planking, to prevent leakage. The first course of logs extends 10 feet beyond the dam and is planked over, forming an apron to protect the gravel bed of the river.

It is said that in the distance of 13 miles from Dixon to Sterling and Rock Falls the banks are generally low, and there is no available power. The total fall between the two levels is about 9 feet.

Sterling and Rock Falls.—Of these two places, Sterling, with 5,087 inhabitants, is situated on the right bank of the river, and Rock Falls, a village with a population of 894, lies directly opposite on the left bank. They are both manufacturing places, and take their power from the pond formed by a dam thrown across the river. An iron highway bridge crosses the stream 400 feet above the dam, and 1,200 feet below is an old bridge crossing at the head of a large island. Still below are several other islands. There is a race on each side, running down from the abutment of the dam.

The natural rapids were about 2 miles long, and the dam is situated a little above the center of the distance, although the greater part of the fall is below. There is altogether on the rapids proper a fall of nearly 15 feet, of which 8 feet is below the foot of the dam, about 5 feet at the dam, and nearly 2 feet in a short rapid just at the head of the slack-water of the pond, some three-quarters of a mile above the dam.

Originally the entire power was owned by the Hydraulic Company of Sterling, and, although no gaugings were made, it was considered to be 30,000 "inches" of water under a head of 6 feet, the height available at the mills. Ten thousand "inches" were sold and guaranteed to Mr. A. P. Smith, of Rock Falls, and the company considers that 20,000 "inches" were left. Of this amount, 8,300 "inches" have been sold, leaving in round numbers 10,000 "inches" yet in the possession of the company.

The Sterling power.—The Sterling race is 600 feet long, 100 feet wide, and about 8 feet deep. There are altogether eight buildings in which the power is utilized. All the wheels are on the river side of the race, and four of the buildings are on the same side; the others have lines of shafting across the race. The following list gives the various industries in the order of their occurrence down-stream, and the number of "inches" of water belonging to each. The letters refer to the positions of the buildings on the maps:

	"Inches".
H and R, machine-shops	1,500
I, flouring-mill	2,500
K, flouring mill	1,500
L, oatmeal-mill (burnt in 1881)	1,000
M, custom grist-mill and pump factory	800
N, O, and P, Novelty Manufacturing Company	1,000

The Rock Falls power.—The Rock Falls race runs down the bank of the river 700 feet, and is about 75 feet wide. It is close to the river, and all the manufactories are between it and one of the streets of the village, their wheels being on the river bank, and the power transmitted across the bank by shafting. The power is taken by seven establishments, which have bought all the power from Mr. Smith, with the exception of 1,800 "inches". It is distributed among the following manufactures:

	"Inches".
A, Industrial Company (various manufactures)	1,000
B, Keystone Company (agricultural implements)	2,000
C, grist-mill	1,200
D, Northwestern Barb-Wire Company	1,000
E, agricultural implements	1,000
F, grist-mill	1,000
G, agricultural implements	1,000

The last-mentioned establishment is across the street, and the power is transmitted to it by wire rope.

The water-power at these places is reliable, because the mills do not use all the water. They can run all the year without special difficulty, except for a few days. If all the power were used there would be more difficulty from scarcity of water, and a careful gauging of the quantity used by each mill would be necessary. Now each uses whatever is required, as there is plenty of water. Several years ago the river was very low, and some of the mills had to shut down during the day, or run only a part of their capacity.

Ice rarely gives any serious trouble. The channel widens below, so that the water passes off readily, and there is not much difficulty from back-water, although there have been ice-gorges below at times. When the mills at Rockford and above shut down on Saturday night the resulting low water begins to be felt on Monday, and the usual stage is not restored until Wednesday, but this does not prevent the running of the mills.

Unimproved power.—The dam can be raised 2 or 3 feet without flooding land, as the banks are high. There is not much inducement to extend the race on the Rock Falls side, as there is about 200 feet of unoccupied space at the lower end of the race, affording room for utilizing the 1,800 "inches" of water yet remaining.

On the Sterling side there is considerable unoccupied space on the race, and it could be very readily continued down to near the foot of the rapids, obtaining a head of at least 10 feet.

There is an old water channel running parallel with the river, which is often occupied now during high water. The race could be run along the side of this. The entire power of the river could be utilized on the Sterling side.

The dam is an old one, built in 1856. The bed is limestone, and the dam is constructed of crib-work, with an equal batter on both sides. It is 1,000 or 1,100 feet long, and curved up-stream.

From Sterling down to Lyndon, a distance of 18 miles, there is about 25 feet of fall. At Como are some slight rapids. Undoubtedly some of the power could be developed, but there is none utilized, and there are no important localities.

Lyndon.—At this place is a partially utilized power, in a rather dilapidated condition. An insecure dam, 800 feet long, extends across the river, and a race runs about 300 feet down the right bank. There are four buildings, but only two of them use the power; these are a grist-mill, with six runs of stones, and a paper-mill. Below them is a building formerly used as a grist-mill, and another which was started by the Grangers as a plow factory, but failed; the head is 7 feet. The proprietor of the paper-mill ordered a 120 horse-power steam-engine, anticipating the carrying out of the dam in the spring of 1881, and it is said that all the owners of the power would be glad to sell out. There is not sufficient capital available to build a good dam.

The river narrows just below the dam, and hence there is difficulty from back-water in freshets. The bed is a weak sandstone, somewhat liable to shale off when exposed.

Formerly an island stood in mid-stream, and the dam ran to it, but now it is nearly washed away. If the place were developed in a thorough manner, a substantial dam and race built, and everything made complete, the power could be depended upon, and would be of value.

Cleveland.—The next utilized water-power is at Cleveland, about 7 miles above the mouth of Green river. At this place is a flouring-mill, on the east side of the river, with four runs of stones, under 4.5 feet head of water.

The fall from Lyndon to the Cleveland level is approximately 20 feet, and the distance 33 miles. The only prominent power which offers for development is at some rapids about 5 miles below the mouth of Rock creek. An island divides the river into two channels, and by throwing a dam across one of them on the rock-bed of the river a head of 6 feet can be obtained. About 10 feet of head is available by extending the dam entirely across the stream.

From Cleveland down to Milan the opportunities for developing a water-power are slight, and the total descent is not over 8 feet, if as much as that. The Milan pond backs 7 miles up-stream, and the rise from it to the mouth of Green river is only 2.2 feet.

Near the mouth of this stream is a rapid where a small head could be obtained, but if a dam were raised so as to give a good head it would probably flood the wheels at Cleveland.

Milan.—The village of Milan is situated upon the south bank of the Rock river, 2.5 miles from where it enters the Mississippi river. It is a place of 845 inhabitants, connected with Rock Island city and Davenport, a few miles distant, by the Chicago, Burlington and Quincy railroad. At Milan are the lowest rapids of the river, and the last water-power.

As seen from the map the river is divided into three channels, and the middle one of these again divided for a short distance. All, with the exception of the southern channel, unite near the town and flow as the Rock river into the Mississippi, 2.5 miles distant. The southern channel, known as Kickapoo slough, pursues a winding course and empties into the Mississippi 5 miles from Milan. It takes a comparatively small portion of the flow. Of the three islands, Vandruff island, which separates the northern and middle channels, has an extent of 90 acres; the others have only a few acres each. The channels distribute the flow of the river and the power, so as to afford great facilities for its development.

There are in all seven establishments, located upon both sides of the river and on islands Nos. 1 and 2. The islands are not greatly elevated above the river.

The bluffs rise directly from the river on the right or north side, but the south bank, after rising 8 or 10 feet, continues nearly level or undulating for several miles back.

The Rock river was classed as a navigable stream by Congress, and on Vandruff island are the remains of an old canal which the government built to pass the rapids. The canal was of no use and is now empty, except where filled with earth. There were great schemes afloat, when Davenport and Rock Island were small villages, for making a large city at this place, and lots were laid out which have long since disappeared in the river. Daniel Webster is said to have lost several thousand dollars by investments in real estate here.

The ownership of the power is distributed among several individuals and companies. A few years ago there was some difference of opinion regarding the rent of a portion of the power, and a survey was made, resulting in the following figures: The low-water flow is 3,931.5 cubic feet per second. Of this, 2,019.9 cubic feet pass through the north or main channel, and belong to the Rock River Improvement and Navigation Company, consisting of the Sears Brothers, who have their mills on the north bank of the river. The remaining 1,911.6 cubic feet are divided between Mr. D. B. Sears, the Heaks property, and the Johnson property. The Johnsons are entitled to 863.1 cubic feet per second from Kickapoo slough, and their mills are situated on the south bank of the river. Mr. Sears owns 524.25 cubic feet, and the Heaks property the same amount. The last two owners can take their water from either of the channels between Vandruff island and island No. 3.

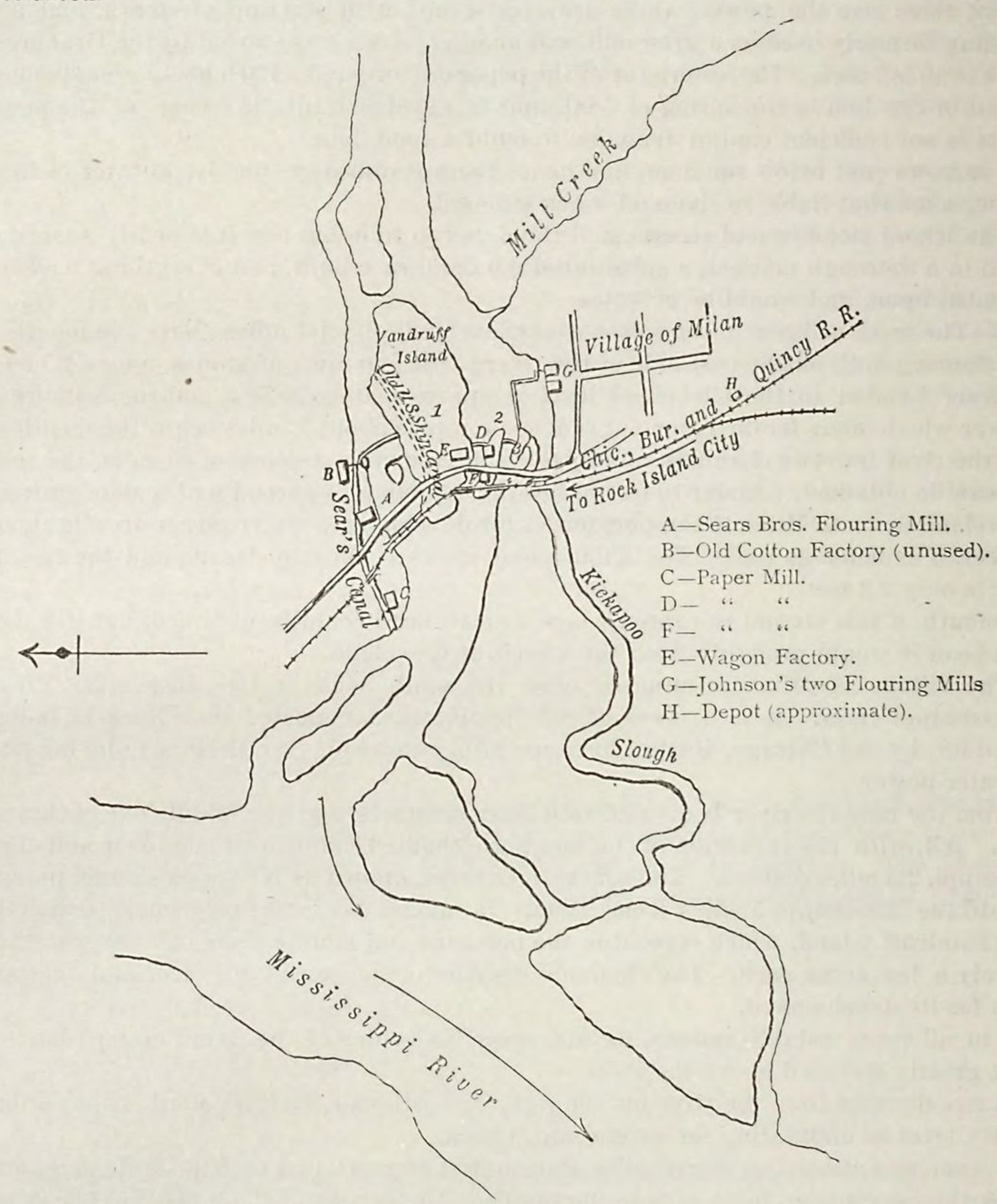
The manufactories are these:

On the south bank are Johnson's two flouring-mills, fed directly from the pond. They use together 150 horse-power under 5.5 feet head of water, but are entitled to a head of 6 feet. Their flow of 863 cubic feet per second under the latter head would give 587 theoretical horse-power.

On island No. 2 are two paper-mills. The one at the lower end of the island is the Heaks mill. It is fed by a canal running along the north side of the island. The canal is 350 feet long, about 32 feet wide, 7 feet deep at the

lower end, and 3½ feet in depth at the upper end. The bed is very uneven, and when the mill is running the water is drawn down and the head much reduced. Ordinarily the head is about 7 feet, and 200 horse-power is used.

The upper paper-mill is situated at the dam, and has a head of 6 feet available. When using the water-power it took about 130 horse-power, but there was difficulty regarding the rental from the Heaks property and steam-power has been substituted.



Sketch map of Rock river, at Milan, Illinois.

On Vandruff island, at the other end of the dam extending between it and island No. 2, is a large brick building erected for a watch factory, but used now as a wagon factory. There is a head of 6.4 feet, and the owners control 600 square "inches" of water at that head.

On the north shore is the power belonging to the Sears Brothers, who are by far the largest owners of the water-power. As previously mentioned, they constitute the Rock River Improvement and Navigation Company.

Because the river is considered a navigable stream by the government, the company was obliged to furnish a navigable channel when it obstructed the natural channel of the river in the improvement of its power. Accordingly it has constructed a canal about 1,700 feet long; 60 feet wide at the bottom, and 7 feet deep in the upper part, and for the remaining distance 40 feet wide at the bottom and 4 feet deep, running along the north bank around the rapids, and provided with a lock, etc., for the passage of vessels. From this canal, which is scarcely, if at all, used for navigation, the water is taken for hydraulic purposes.

There are three buildings on the canal; one large brick building at the head was once a cotton factory, but the machinery has all been removed, and the place is lying idle. The power was transmitted across the canal by a wire rope from the wheel-house, situated directly at the abutment of the dam. A head of about 10 feet is available. Just above where the road crosses the canal is Sears' flouring-mill, with eleven runs of stones under a head of 11½ feet. At the foot of the canal is a paper-mill with 12½ feet head of water on its wheels, and using about 150 horse-power.

Peculiar nature of the power.—With only about 700 horse-power in actual use, and 2,500 available even with the lowest head used, it will be readily seen that there need be no scarcity of water. There is no trouble from low water, but when the power is further developed it will be necessary to define more accurately the flow used by the several companies. As it is now, the mills have to shut down usually two or three weeks out of the year, and this is not due to scarcity of water, but to backwater. One peculiarity is that the Johnson mills upon Kickapoo slough are very differently affected from those on the other channel of the river. This is due to the difference in the channels, and the imperfection in the plan of the Johnson dam and wing-wall.

There is a fall of only about 2 feet from the tail-race of Sears' mill to the Mississippi by the direct channel of the river, and the result is that when the Mississippi is very high it will back up the river and drown the wheels at Milan, with the exception of those of the Johnson mills, which, situated on the slough entering the Mississippi farther down, are not so affected by backwater from the latter stream. On the other hand, when there is a freshet on the Rock river itself, then the Johnson mills are stopped, while the other mills experience little difficulty unless the Mississippi is also high. The reason is that there are 800 feet of overflow on the dam and wing-dam into Kickapoo slough, while the slough contracts a short distance below to about 140 feet in width; hence the water backs up so as to drown out the wheels. However, either of these causes of stoppage acts only for a short time and is not of much importance.

About once in every decade there is an extraordinary rise, when the river backs up very badly upon the mills at Milan. Thus, in June of 1880, boats could be rowed up-stream directly over the crests of the dams.

The ice goes out very heavy at times and is likely to injure the dams. Occasionally the mills are troubled by it and slightly by anchor-ice before the river is well frozen over.

Utilized power.—The power could reasonably be developed so that a head of at least 7 feet would be available throughout, and the greater part of the flow could be utilized under a head of 10 to 12 feet. Calling 9 feet the average, the total power would be 4,033 theoretical horse-power. With not more than 700 horse-power in use there remains at least 3,000 horse-power available, for the utilization of which there are excellent facilities.

Without mentioning the opportunities of freightage, with the railroad crossing the river at the foot of Vandruff island, and the ease of communication with the sites by teams, the nature of the localities is such as to recommend their occupation. There are a great number of sites on Sears' canal, with a head varying from 10 to 12½ feet. With their flow of 2,019.9 cubic feet per second, they have 2,520 theoretical horse-power available under a head of 11 feet.

A canal could be run down Vandruff island from the dam across the north channel. There is an unused bulkhead on the canal on island No. 2, and on both islands Nos. 2 and 3 are sites capable of improvement when required. On the south bank of Kickapoo slough a canal could be readily extended for half a mile and good sites obtained. The Johnsons own the river-front above the railroad, and could without difficulty construct the canal.

Dams.—There are four dams at Milan running between the islands, and forming one pond above them, which backs 7 miles up-stream.

The bed of the river is limestone ledge. There are two varieties of limestone—a light gray, which makes a good building stone, and is used for Sears' mill, and a finer-grained, bluish variety, which is very irregular, breaks out in chunks instead of slabs, and disintegrates on exposure. In the bluffs a ferruginous sandstone occurs, and a seam of coal several inches thick.

The dam crossing the north channel is 640 feet long and 12 feet high. It consists of a timber frame, each bent being about 30 feet long. The sill pieces were sunk into the bed of the river. For an apron horizontal stringers were let into the front posts, and planking was spiked to these. The ice cut it away, and then a spar-dam of logs was built into the face of the old dam to act as an apron.

The dam between islands Nos. 1 and 2 is 320 feet long, and that between islands Nos. 2 and 3 is 240 feet long. They have essentially the same construction as that just described, except that the apron is not replaced by the log work.

Connecting island No. 3 with the large island below it is a dike, not overflowed. A wing-dam runs up-stream 300 feet to the Johnson dam, which extends straight across the channel 500 feet to the south shore. This is an old spar dam built in about the year 1855, and leaks badly. It is 5½ feet high and 24 feet broad at the base. Before the Sears' dam was built across the north channel, the Johnson dam extended entirely across to Vandruff island, and the slough was used as a pocket.

TRIBUTARIES OF THE ROCK RIVER.

The branches of the Rock river are less important than would be supposed for a river of its size. The table of tributaries gives the chief ones in their order from the source down, and the data concerning them. The average for the entire basin is taken in calculating their flow, although, as described on preceding pages, such a method can only give a rough approximation.

On the seven tributaries given in the table there is a total of 49 establishments, of which all but five are flouring- and grist-mills, mainly doing merely local grinding. The remaining five are wood-working establishments, saw-mills, etc. There are a number of mills upon the smaller tributaries distributed through the basin. The statistics regarding these powers have been taken from the census returns.

Crawfish river.—The Crawfish is the first tributary of much size below the headwaters of the Rock. It drains 798 square miles, but is a sluggish stream, and has only one utilized power. This is occupied by a flouring-mill, using 80 horse-power under a head of 10½ feet, at Milford, some 10 or 15 miles above the mouth. On the Beaver Lake branch there is a mill using 20 horse-power under a head of 14 feet, at the outlet of Beaver Dam lake, and there are also two woolen-mills, taking 52 and 45 horse-power under heads of 8 and 10 feet. The lake is an artificial one formed by the mill-dam.

Catfish river.—The Catfish river is the outlet of the four fine lakes in the vicinity of Madison, Wisconsin. There are five establishments using the power of the river; four flouring-mills taking a total of 300 horse-power under heads of 4 and 8 feet, and one wagon shop using 17 horse-power under a head of 7 feet. The principal mill is at Stoughton, with five or six runs, taking 117 horse-power under 8 feet head of water. If the Madison lakes were regulated exclusively in the interests of the water-powers, there would be great regularity in the flow, but they are always maintained at as high a level as possible, and not allowed to be drawn down.

Pecatonica river.—The Pecatonica is the largest branch of the Rock river, and has more improved powers than any other tributary stream. There are eighteen flouring- and grist-mills—mostly small ones—upon it, two wood-working shops, and a manufactory of agricultural implements. The total power used is 688 horse-power, and the heads of water vary from 20 to 4 feet.

The largest mill is at Freeport, in Illinois, and has five runs of stones, taking 130 horse-power under a head of 5 feet. There are also at Freeport a three-run mill and a small wood-working shop. They are not especially troubled with scarcity of water, but it is not probable that any more mills could be accommodated in dry seasons.

At Freeport the river is from 130 to 150 feet wide, with low rim-banks of earth, and these characterize it for a large part of its course. The upper portion is in the "driftless area", in Wisconsin, already described. The Sugar river, an important tributary draining about one-third of the basin, enters from the north, some 7 miles from the junction with the Rock river. There are eight establishments upon it, all flouring- and grist-mills, using 317 horse-power under from 6 to 12 feet head of water. The largest mill takes 120 horse-power under a head of 10 feet. Along the lower part of the stream especially, the bed and banks are inferior for dams and other hydraulic works, and in places are almost a quicksand.

Kishwaukee river.—The Kishwaukee drains 1,266 square miles. Ten or 12 miles above the mouth it divides into the North and South branches, the North branch draining rather more than half the basin. The entire amount of power used is 179 horse-power, taken by six flouring- and grist-mills and one small saw-mill. The head varies from 4 to 14 feet. There are two grist-mills on the South branch, each with two runs of stones.

There is a two-run mill at New Milford, on the main river below the junction, and the remaining three mills are on the North branch; a three-run mill at Cherry Valley, a four-run mill at Belvidere, and a two-run mill at Garden Prairie, with only 4 feet head of water. There are no mills on the river above this.

The Kishwaukee is 150 or 200 feet wide at Belvidere, some 10 miles above the junction with the South branch. It is not a very rapid stream, and the banks are generally low. It ranks among the average rivers of this region as regards freshets and low water.

Piseasaw creek enters the Kishwaukee river just above Belvidere. There are four mills upon it, all using two runs and from 6 to 9 feet head of water, with the exception of the one at the mouth. This is called the "Good Thunder mill", the name of a celebrated Indian chief, and is fed by a race leading from the creek to the Kishwaukee river, giving a head of 12 feet. There are three runs of stones and a set of rollers.

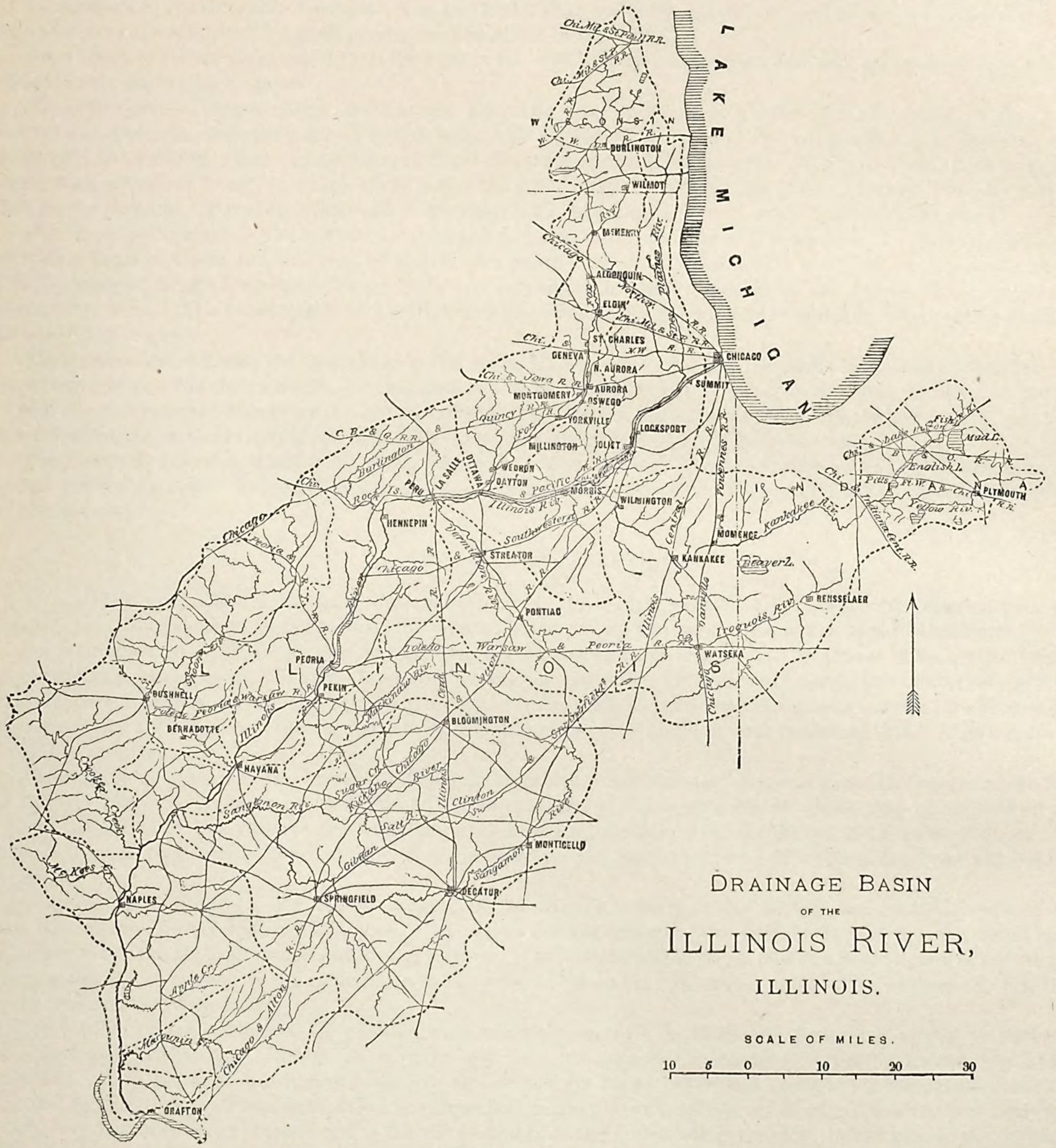
Elkhorn and Rock creeks.—The Elkhorn and Rock creeks are minor streams, each with several small custom mills upon it. At the mouth of Elkhorn creek, at Como, there was, before the time of railroads in that region, a flouring-mill which was among the first in the state in importance. The water was brought in a race across a point of land from the creek to Rock river.

Green river.—Although Green river drains an area of 1,131 square miles, there are no developed water powers upon it. At one time there was a small mill at Oakley, 6 or 7 miles from the mouth, but it is not now used. The basin of the river is swampy, and it is a sluggish stream, with low banks, poorly adapted for water-power.

TRIBUTARIES OF THE EAST SIDE OF THE MISSISSIPPI, FROM THE ROCK TO THE ILLINOIS RIVER.

The distance by the Mississippi, from the mouth of the river just described to the junction with the Illinois, is 267 miles, and although the Iowa, the Des Moines, and several other streams of more or less importance enter from the west, no tributaries of noteworthy size join the Mississippi between the points named in Illinois. This is owing to the position of the divide between the Illinois basin and the Mississippi; it passes within from 10 to 20 miles of the latter river for four-fifths of the distance from the Illinois to the Rock, and then recedes, so as to leave a strip averaging about 40 miles across.

In this section are three streams, Edwards river, Pope creek, and Henderson river, which merit a passing notice.



DRAINAGE BASIN
OF THE
ILLINOIS RIVER,
ILLINOIS.

The land is decidedly undulating and the soil is rather light for wheat, but better adapted to the raising of corn, which is the chief crop. There is a large amount of timber scattered over the region, including elm, oak, hickory, sycamore, and also black walnut; but a large part of this was bought up in the winter of 1880–'81 and shipped to Saint Louis.

Henderson and Edwards rivers are the largest of the three streams, and Pope creek merely drains a narrow strip between them. They all appear to be average streams as regards regularity of flow, not true prairie streams, but yet subject to considerable freshets. The bed and banks are chiefly earth, and often low, so that dams back the water over the land, but in some places the bed is cut to the rock.

Pope creek is rather more rapid than the other two, which do not have much fall and are more or less subject to back-water during high stages.

Edwards river.—There are three mills on the Edwards river; one, about 7 miles from the mouth, with a head of 5 feet and two runs of stones; one at Millersburg, with a head of 7½ feet and two runs, and one at Opheim, with a head of 8 feet and two runs. In addition to these are some undeveloped powers. North of Viola there is a good power, with a head of 7 feet, at which there was once a mill, but the owner tore it down rather than pay further damages for flowage. Between Aledo and Viola there was once a carding-mill, with 7 feet head of water.

Pope creek.—Pope creek has only two developed water-powers; one, about 6 miles from the mouth, where is a mill with a head of 6 feet and two runs of stones, and another, south of Aledo, with a mill using the same number of stones under a head of 8½ feet. These mills can run eleven or twelve months of the year. There are several unutilized powers. At a point 1 mile or 2 miles below Suez is a privilege with a head of 6 feet, where was a carding-mill several years ago.

Henderson river.—There are two mills on the main Henderson river. Jack's Mills is a small settlement just east of Oquawka. The flouring-mill at that place has three runs of stones under a head of 9 or 10 feet. A part of the year the mill cannot be operated, on account of scarcity of water, but at times there is more power than required. About 3 miles below Cedar creek is a mill with three runs under 12 or 15 feet head of water.

The South Henderson, which joins the main stream about half way between Oquawka and its mouth, is small, but has a rapid descent. There are also two mills on Cedar creek and one on Fall creek, both of them tributaries of the Henderson.

THE ILLINOIS RIVER.

At a distance of 1,180 miles from the source of the Mississippi, and 24 miles above its junction with the Missouri, the Illinois enters from the east, the most extensive of all the tributaries of the upper Mississippi.

Its drainage area of 29,013 square miles is distributed among three states: 24,726 square miles are in Illinois, and extend in a broad band, 250 miles long and averaging 100 miles wide, directly across the center of the state in a northeast direction. From the upper extremity of this band are two projections—one north into Wisconsin, and comprising 1,080 square miles in that state; the other east into Indiana, and including 3,207 square miles of its northern portion.

The eastern projection is the basin of the Kankakee river, while the northern one forms the basins of the Fox and the Des Plaines rivers, and it is the union of the drainage of these projections which may be considered the origin of the Illinois. The name is applied to the river from the junction of the Kankakee and the Des Plaines. Its course is from 20 to 40 miles from the line of water-shed on the northwest, and 60 to 80 miles from that on the southeast.

Character of the country.—The region drained by the Illinois is level or undulating, and includes some of the finest land of the United States. The broad strip across Illinois embraces the greater part of that deep rich loam which has made the state so prominent for agriculture. Corn is the staple crop; winter wheat is grown, but wheat-raising is not so pre-eminently the industry as in Minnesota; the soil is lighter and better adapted to corn. Grazing is very extensively carried on.

The fertility of the basin and its position with reference to the lines of communication have led to its early settlement and prosperity. Except in swamps and extreme points, the country is pretty thoroughly under cultivation. The population is about 1,038,000, and numerous large towns and cities are interspersed along the river and its tributaries. Prominent above all others is Chicago; strictly speaking not within the limits of drainage, its influence has been most pronounced in the development of the surrounding country, and largely to the presence of this great center of trade are due the manufacturing industries to be found. The development of the water-powers of the Illinois basin is more or less the result of the phenomenal growth of Chicago, coincident with the topographical relations; and later will be shown the relation of the available powers to this city.

With so many thriving towns, it is unnecessary to say that the railroad facilities are excellent. A net-work of roads covers almost the entire basin, and many of them are "through lines" between the East and West.

The river itself is an important channel of trade. Like the Fox and the Wisconsin rivers of Wisconsin, the Illinois and the Des Plaines river, which passes so near lake Michigan, offer great advantages for navigation from the great lakes to the Mississippi, and ever since the French commander La Salle made the portage and descended the Illinois it has been used as a channel between the two great water routes.

A canal 100 miles long, called the Illinois and Michigan canal, starts from lake Michigan at Chicago, and cutting through the low summit enters the Des Plaines River valley. Crossing the river at Joliet it runs along the right bank of the Illinois to Peru, where it enters the river, and from there to the Mississippi, a distance of 230 miles, there is navigation, partly natural and partly artificial slack-water, caused by two dams—one at Copperas creek, 130 miles above the mouth of the river, and one at Henry, 190 miles above the mouth.

The construction of a canal 65 miles long from Hennepin, on the Illinois river, about 20 miles below the terminus of the Illinois and Michigan canal, to the Mississippi at Rock Island has been much discussed. The cost is estimated at from four to four and a half million dollars. A feeder is also talked of, starting from the Rock river at Dixon and connecting with the canal, and to be navigable.

System of drainage.—Because of the form of the basin, the drainage into the Illinois is quite evenly distributed along its course. Running, as it does, much nearer the northwestern than the southeastern line of water-shed, there are more important tributaries entering from the left than from the right bank of the river. The three principal streams are the Sangamon, the Kankakee, and the Fox rivers, the first two of which are on the left side of the main river.

The chief tributaries, given in their order from source to mouth, are these:

RIGHT BANK.		LEFT BANK.	
Stream.	Drainage area.	Stream.	Drainage area.
	Sq. miles.		*Sq. miles.*
Des Plaines river	*a* 1,758	Kankakee river	5,302
Fox river	2,697	Vermillion river	1,413
Spoon river	1,905	Mackinaw river	1,182
Crooked creek	1,286	Sangamon river	5,592
		Macoupin creek	1,000

a Approximate.

The total area drained by these nine tributaries is 22,135 square miles, leaving 6,878 square miles to be drained by the smaller streams which flow into the Illinois all along its course.

As previously mentioned, the Illinois proper is formed by the junction of the Kankakee and the Des Plaines rivers, starting off from the first with a tributary area of over 7,000 square miles; 33 miles below it receives the Fox river, the Mazon river and Aux Sable creek entering above it; then the Vermillion, 15 miles below, near the terminus of the canal. About 90 miles below the mouth of the Vermillion the Mackinaw enters, but in the intervening distance are several important creeks, as Big Bureau, Sandy, and Kickapoo. Next is Spoon river, about 20 miles below the Mackinaw; then the Sangamon, 20 miles below; then Crooked creek, about 15 miles below the Sangamon; and finally, Macoupin creek, about 18 miles above the mouth of the river and 65 miles below Crooked creek. Between the last two streams mentioned are McKee's creek, Mauvaise Terre creek, Apple creek, and several others.

Although the drainage area is quite uniformly distributed along the length of the basin, the utilized water-power, and almost all the available power, is confined to the upper portion. The census returns show a total of only 782 horse-power utilized below the Fox river, by thirty small mills averaging 26 horse-power each, the largest taking 64 horse-power.

Practically all the utilized water-power of the basin, amounting, according to the census returns, to 10,144 horse-power, is located on the main river and canal above the mouth of the Fox at Ottawa, on the Fox itself, the Kankakee, and the Des Plaines. The water-power of the Illinois basin is thus included within a radius of 60 miles from Chicago from west to south. The Fox, Des Plaines, and Kankakee rivers, including an area of 10,000 square miles, descend from a table-land into the valley of the Illinois, with rapid descent over rocky beds, and give rise to extensive water-powers, easily developed.

The through lines of railroad between Chicago and the West and Southwest cross the rivers or run along their valleys, and the canal stands ready for the manufacturer's use. As might be supposed, the power is largely used for general manufacturing suited to the wants of a large population, and is not devoted very exclusively to any special branch of industry.

The northern limit of the coal-fields of Illinois is in this region, and these add to its natural wealth and development. It is largely to the existence of the rich beds of coal in the basin that is due the undeveloped state of the powers, such as they are, which exist on the lower tributaries. In the early history of the state, before coal was so cheap, there were many grist- and saw-mills on the Sangamon, the Vermillion, and other streams, but from the difficulty of maintaining dams, the increasing unsteadiness of the streams as the country was cultivated, and the cheapness of coal for fuel, these were gradually abandoned, and now few remain. Owing to the unpromising character of these rivers, except in favored localities, and the ease of obtaining fuel, there is no special inducement to develop the water-powers, and probably all this portion of Illinois will remain practically dependent upon other than hydraulic-power for its manufacturing.

Flow of the streams.—The average rainfall of the Illinois basin is 37 inches per year, nor does it vary far from this amount in any part except south of lake Michigan, where an entirely local increase, caused apparently by the proximity of the lake, raises the annual precipitation to about 45 inches over a large portion of the basin of the Kankakee.

Although a fair amount of moisture falls upon the basin, the Illinois dwindles to a small stream in the dry season. In the tables and remarks concerning the tributaries of the Mississippi this has been already dwelt upon. There is no way of accounting for the extremely small "ordinary low flow" of 2,000 cubic feet per second, estimated by the United States engineer in charge, except by the very level and prairie character of so much of the basin in Illinois.

The Sangamon, and in fact all the streams below the Fox, fall to a very low stage in summer and fall, the water all passing off in heavy freshets, sometimes of several weeks' duration. There are few swamps, lakes, etc., to hold the water back, and the well-nigh universal testimony is to the increasing fluctuations of the streams since the draining of swamps and the clearing of the land. Nor is the Fox to be entirely excluded from the category of "low-flow" streams. Rising among some lakes of Wisconsin and northern Illinois, the summer flow is maintained rather better than in the case of the streams just mentioned, but still it falls away in dry seasons, and the gaugings of the United States engineers place its flow (presumably at a low stage) at 526 cubic feet per second, or 0.195 cubic foot per second per square mile.

The Des Plaines is a stream much resembling the lower tributaries in character of flow, but it is constantly fed by an average discharge from lake Michigan, through the canal, of 373 cubic feet per second, an item of no small moment to a stream naturally draining only about 1,758 square miles.

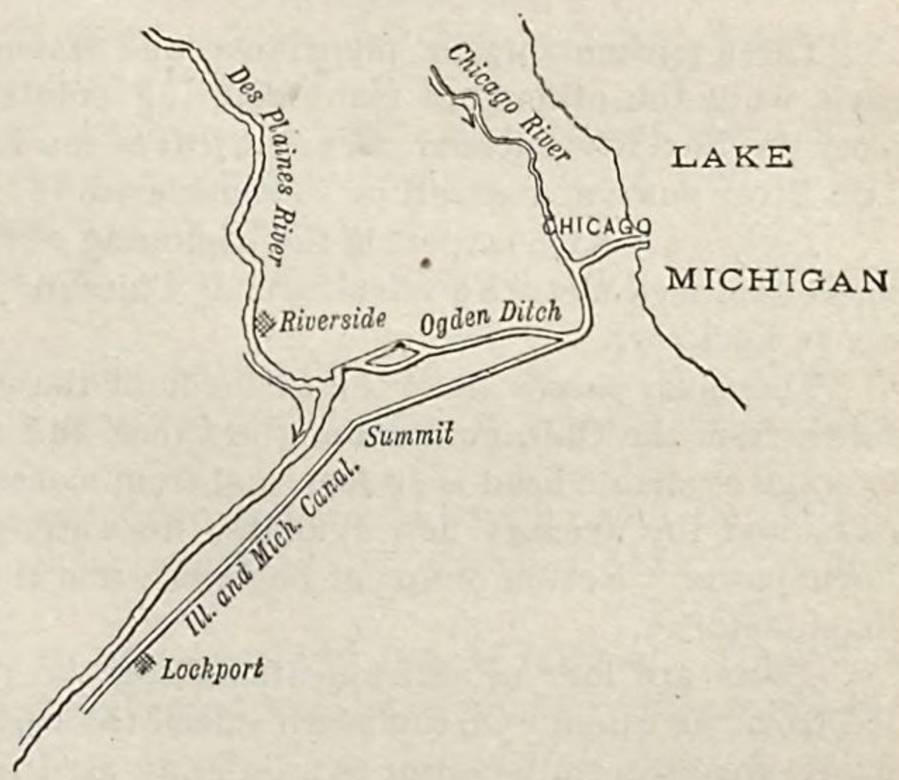
The Kankakee is to the Illinois basin what the Wisconsin, Chippewa, and other similar streams, are to the upper Mississippi. Swamps characterize its entire course in Indiana, and these, with the lakes, serve very materially to maintain the flow during summer and fall. Engineers familiar with the river estimate the ordinary low flow to be 1,300 cubic feet per second, or 0.245 cubic foot per second per square mile. This appears low, but it must be remembered that its large tributary, the Iroquois, flows mainly from a level or rolling prairie, and is an unsteady stream.

Enough may be gathered from the preceding remarks to make it evident that the most steady drainage of the Illinois basin is in the upper part, where the developed water-powers are situated, and most fortunate is it that such is the case; for, if the Kankakee and the Fox dwindled in summer to shallow brooks falling over their rocky beds, the otherwise fine powers would be of little value.

The average flow of 373 cubic feet per second through the canal from lake Michigan plays an important part in the water-powers along the canal and the Des Plaines river.

POWERS ON THE CANAL, AND ON THE DES PLAINES AND THE MAIN RIVERS.

Relation of the rivers, canal, and lake.—Because of the relation of the canal to the Des Plaines, and then of both to the Illinois itself below the mouth of the Kankakee, it seems most advisable to start from Chicago and pass down the canal and the Des Plaines river to the junction with the Kankakee, and then down the main river, describing the water-powers in order as they are met with.



The Des Plaines river rises in Wisconsin and flows nearly parallel with the lake Michigan shore to a point about 10 miles southwest of Chicago; it then turns southwest, and flows 40 miles to the junction with the Kankakee. In this distance the valley averages about 1 mile wide, and consists of a rather shallow trough cut out of limestone. This is only scantily covered with a thin bed of drift, and the banks of the river are consequently very low. The canal starts from the lake at Chicago and crosses to the river at Summit, 11 miles from the city. It then passes down the left side of the Des Plaines for 25 miles to Joliet, where it enters the river, and then crosses to the right bank.

From Joliet down to La Salle it runs along the right bank of the Des Plaines to the Illinois, and along the bank of the Illinois river. A feeder, 4 miles long, starts from the "state dam" on the Kankakee river, and supplies the canal with water, and one of the same length takes water from the Fox river at Dayton, and enters the canal at Ottawa, at the junction of the Fox and the Illinois rivers. There are also the Calumet feeder, near Chicago, and others of no importance to this report.

The summit between the lake and the Des Plaines valley, in the vicinity of Chicago, does not exceed 20 feet in elevation above the lake, and the canal, which formerly passed this by a lock, now goes through the "deep cut" excavated from 6 to 10 feet in the limestone.

From the lake down to Lockport, a distance of 32 miles, there is now a continuous level, with a fall of 3 feet in the water surface. The bottom line of the canal is 6 feet below the surface of low water in lake Michigan. The canal really enters the lake through the Chicago river, a small stream. The Ogden-Wentworth ditch, called by some the south branch of the Chicago river, connects the canal with the Des Plaines near Summit.

The Des Plaines, Ogden ditch, and the canal are nearly on a level, and hence the direction of the flow depends largely on the height of water in the river, and the level of lake Michigan. When the Des Plaines is high it flows through Ogden ditch into the lake, and also down the canal. A strong north wind will increase the flow from the lake into the canal, while a south wind may so diminish it as to interfere with the water-powers below.

The average depth of water in the canal at Bridgeport, near its mouth, is 9 feet, and with this depth the flow from the canal is 375 cubic feet per second.

Distribution of fall and power.—The total fall from the level of lake Michigan down to the Illinois at the foot of the canal below La Salle is 141 feet, and half of this occurs in the distance of 18 miles from Lockport, on the Des Plaines, to the junction with the Kankakee. The distance from the Kankakee to the foot of the canal is 51 miles.

There is 50 feet fall concentrated in the 4 miles between Lockport and Joliet.

The total descent of the Illinois from the foot of the canal to where it enters the Mississippi at Grafton is only 33 feet. This portion of the river was formerly under the control of the state, but now Major Lydecker, United States engineers, stationed at Chicago, has charge of it. He proposes to build two slack-water dams in addition to the two now existing; one at La Grange, with 7 feet 4 inches lift, and one at Kampsville, 30 miles from the mouth, with 7 feet lift. These will render the navigation of the river practicable at all times.

These remarks upon the levels of the canal and river will serve to give a general idea of the distribution of the water-powers.

The canal belongs to the state of Illinois, and the policy is to lease power from it where there is a favorable locality and sufficient surplus over the flow required for navigation. As a consequence there are a number of utilized powers upon the canal. The ordinary rate of leasing is $200 per annum for 40 horse-power, in quarterly payments in advance.

The localities of utilized power on the canal, Des Plaines river, and Illinois river, in the order of occurrence, are these:

Place.	Distance from summit.	Remarks.
	Miles.	
Lockport	21	Power from the canal.
Joliet	25	Three levels. Canal enters the Des Plaines and power from the river.
Channahon	36	Power from the canal.
Aux Sable	42	Do.
Marseilles	66	Power from the Illinois river.
Ottawa	73	Power from the Fox River feeder.

These powers vary in importance and extent. Channahon and Aux Sable have only one or two small mills each, while the others are manufacturing points of more or less importance. There are some mills taking water from the Fox River feeder, where it leaves the Fox river at Dayton, but they strictly come under the head of the Fox River powers, and will be so considered.

Lockport.—At Lockport is the beginning of the rapid descent of 50 feet in the 4 miles down to Joliet, and here is the first lock met with after leaving Chicago. The rapid descent in the Des Plaines river begins half a mile above Lockport.

The canal passes along the east side of the valley, several hundred feet from the river. The power is entirely taken from the Chicago level of the canal, and the water from the wheels runs into the Des Plaines river. The average available head is 19 feet, and from measurements made in 1872 Mr. D. C. Jenne, the engineer of the canal, estimated the average flow available for water-power to be 352.65 cubic feet per second, giving 760 theoretical horse power. Norton & Co., of Lockport, rent the power from the state, and sublease a portion of it to the different manufactories.

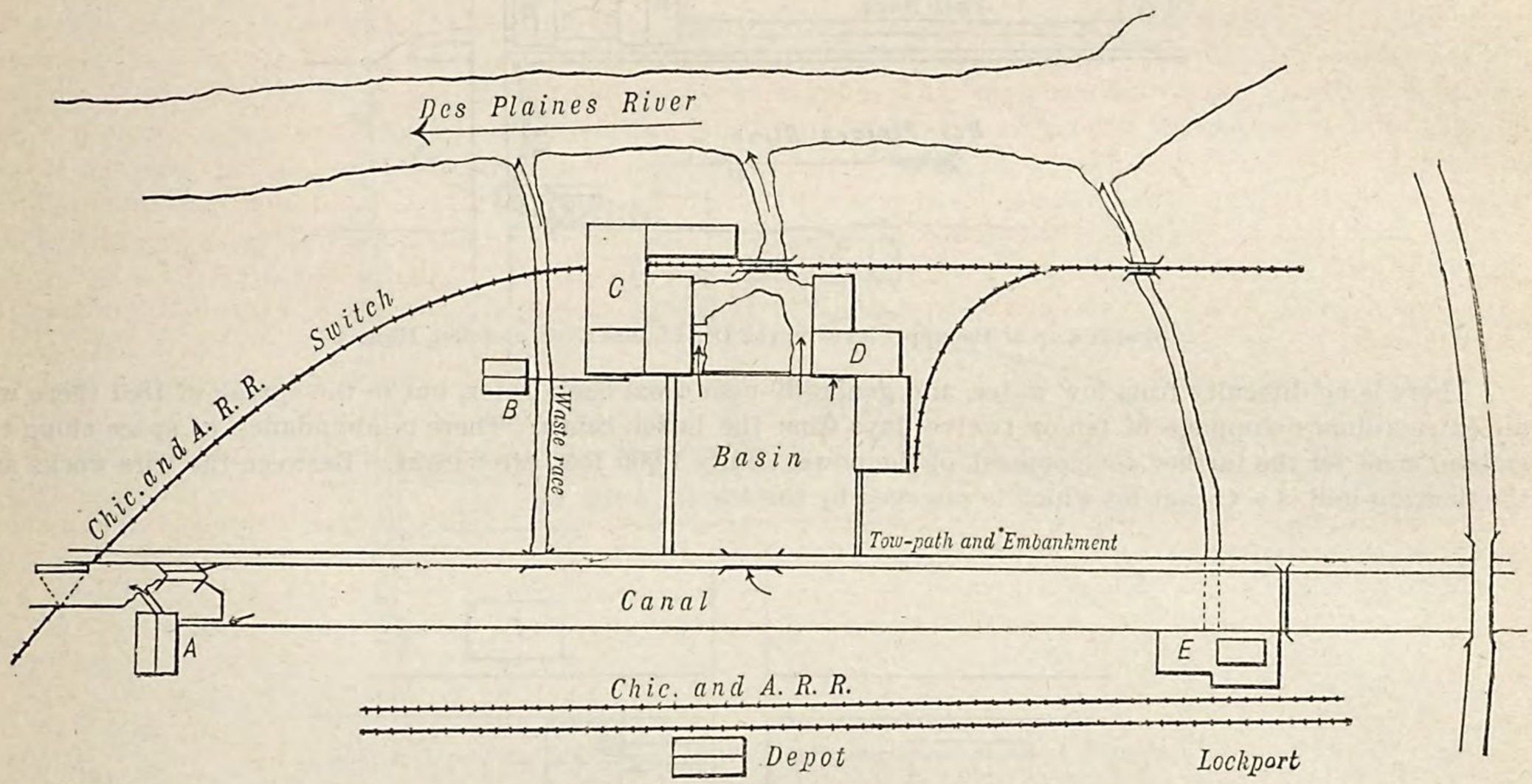
There are four establishments taking the power, of which two are situated at a basin about 300 feet square, fed from the canal. On the north side of the basin is a flouring-mill, and on the south side a paper-mill, from which a wire rope transmits power to a building used for preparing the straw.

Some distance above the basin, and on the other side of the canal from the river, is a building used for a grain elevator, a planing-mill, a machine-shop, and to contain the pumps for supplying Lockport with water. At the lock below the basin is a small tannery, using the fall at the lock. The tail-race for the elevator passes under the canal and through an excavation in the limestone to the river.

The limestone here is a superior quality for building; the Joliet quarries, 4 miles below, are noted. The flouring-mill has a capacity of 700 barrels per day, and the paper-mill a capacity of 20 tons per day. The latter

uses 200 horse-power, under a head of 18 feet, the same head that is used by the flouring-mill. The elevator, etc., use 175 horse-power, under a head of 16 feet, and the tannery about 20 horse-power, under a head of 8 or 10 feet.

The head available varies from 18 to 20 feet. The manufactories cannot draw so as to lower the head much beyond 18 inches, as that would interfere with navigation, and consequently when the lake is low they have to shut down; but there is not so much difficulty arising from this account as from low water due to freezing. A thick layer of ice, by diminishing the water-way and increasing friction, sometimes so diminishes the flow as to stop the mills. The flouring-mill cannot usually run in winter over half its usual power. Norton & Co. pay a rebate to the manufactories whenever they are stopped by lack of water more than thirty days of the year, but this has never been paid for low water of summer alone. There is very little anchor-ice, and back-water does not stop the mills, although high water in the Des Plaines is not accompanied by a corresponding rise in the canal.



Sketch map of the mills and hydraulic basin at Lockport, Illinois.

It is evident that there is little, if any, available power remaining on this level of the canal with the present flow. At times, however, there is a large volume of water flowing through the waste-weir into the river.

Power on the Des Plaines.—About half a mile below Lockport is an old grist-mill, on the Des Plaines river, with four runs of stones, under a head of 8 feet. The improvement was made in 1838, and there was once a saw-mill also. The dam is 400 feet long, built of stone, resting upon the limestone bed of the river.

Unutilized power, Lockport to Joliet.—As the surplus water of the canal is taken at Lockport there is no unutilized power on it above Joliet, where it enters the Des Plaines river. On the river itself there is no utilized power above the one just described. It is a very unsteady stream, and its power is of very little practical value above where the surplus from the canal is discharged into it at Lockport. The surplus from the canal is considered to have doubled the natural average flow of the river.

Of the 50 feet of fall from half a mile above Lockport down to Joliet, only 8 feet are in use. It is possible to improve the power, but the banks are very low, and a dam giving a good head would have to cross extensive flats.

The limestone strata furnish excellent foundations for buildings.

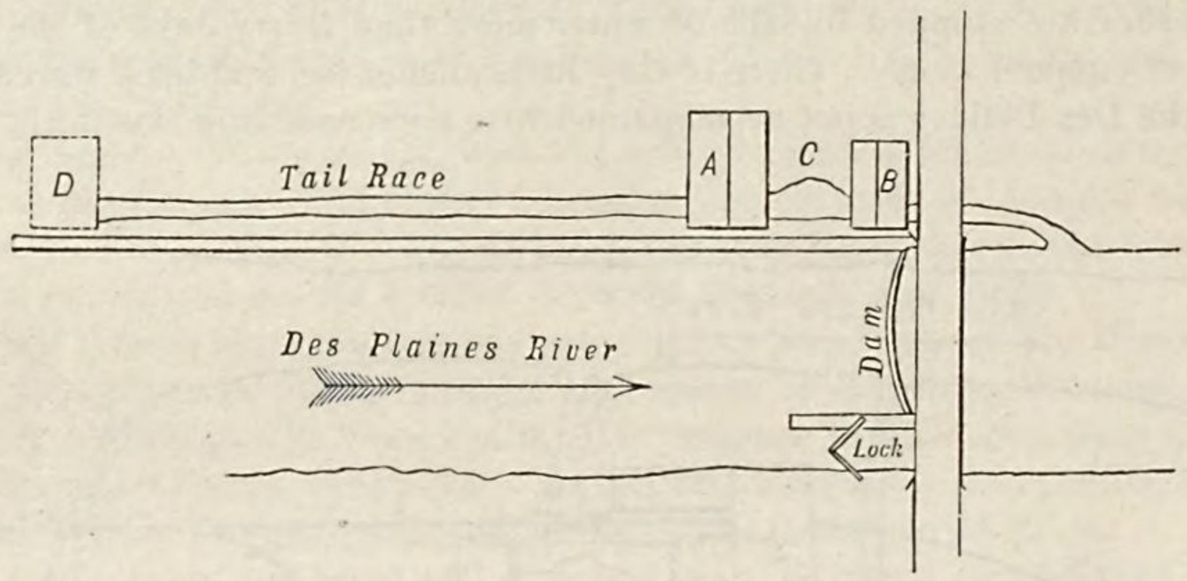
Should the flow through the canal be largely increased, as is contemplated, it would supply, with the 50 feet of fall, a large amount of power; and this could probably be more cheaply utilized from the canal than if the flow were discharged into the river at Lockport and then taken.

Joliet.—Joliet is a town of 11,756 inhabitants and is touched by several important lines of railroad. The Joliet Iron Works are situated there, and these, with several other manufacturing establishments using either steam- or water-power, render it an important manufacturing place.

The total fall of the river within the city is about 25 feet, and this is divided into three levels by 3 dams, of which the upper two belong to the state, and the third to one of the citizens. The canal enters the river in the upper level; the line of navigation then passes the upper dam by a lock into the middle level, from which the canal starts down the right bank of the river.

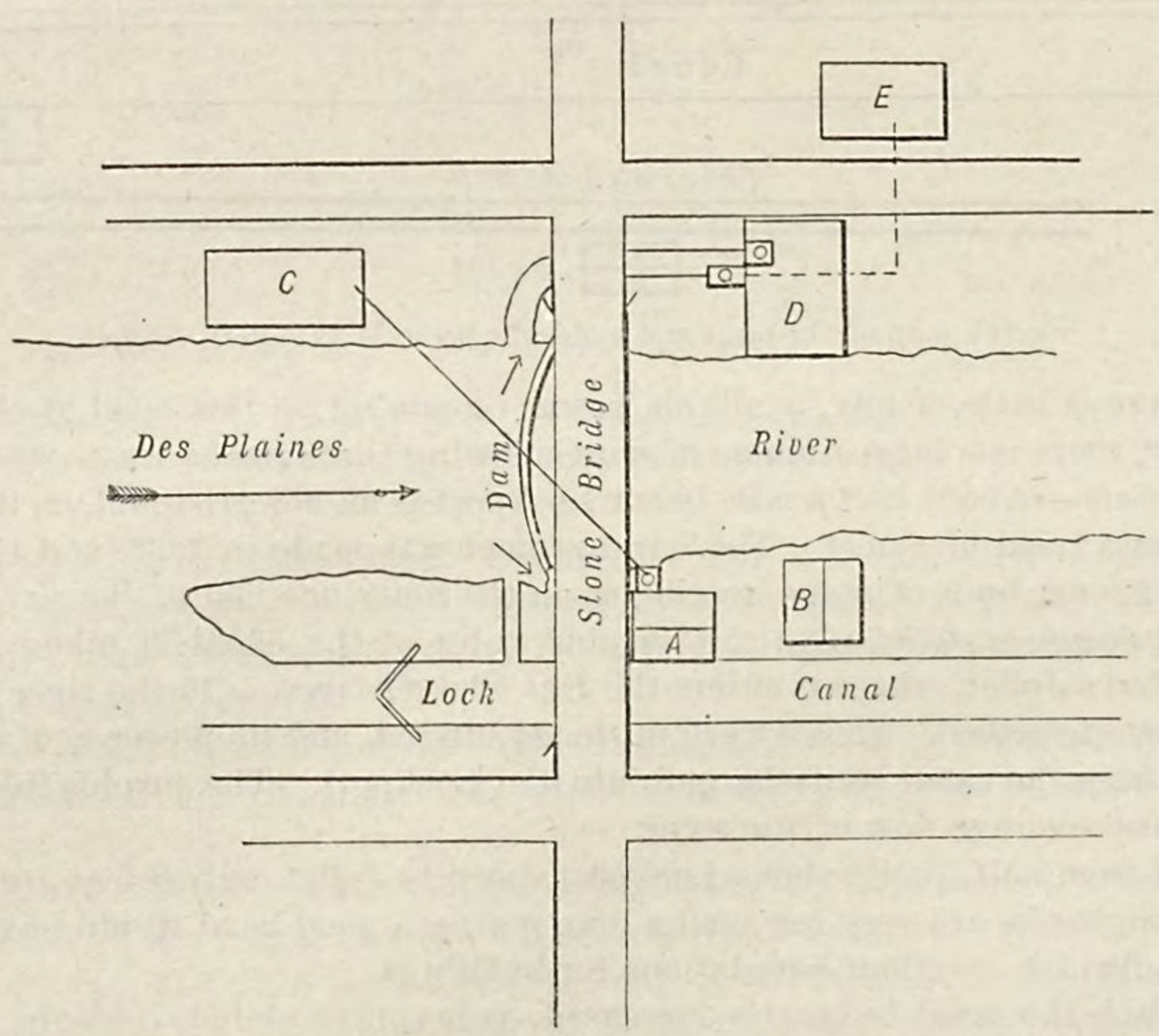
Upper level at Joliet.—At the upper level a levee extends 2,000 feet or more up the left bank from the dam, and behind this are the mills, with a tail-race running along the foot of the levee and entering the river a short distance below the dam.

The power is rented from the state by a Mr. Hyde, who sub-lets part and uses a portion himself, paying the state $1,480 per year. He has practically the entire flow of the river and canal, because the amount required to work the lock is small. Mr. Jenne calculated the total power available to be 258 horse-power under a head of 9 feet. But little of the power is in use; there is a wire-works just at the dam, using 45 horse-power under a head of 12 feet, and paying $1,000 per year rent, and Hyde's flouring-mill, with six runs of stones under a head of 12 feet. Several hundred feet above the flouring-mill a paper-mill was being built in 1881, which was expected to use a 60-inch and a 30-inch wheel, each under a head of 7 feet.



Sketch map of the upper level on the Des Plaines river, at Joliet, Illinois.

There is no difficulty from low water, and generally none from back-water, but in the spring of 1881 there was an extraordinary stoppage of ten or twelve days from the latter cause. There is abundance of space along the embankment for the further development of the power; fully 1,000 feet are vacant. Between the wire-works and the flouring-mill is a vacant lot which is reserved by the state.



Sketch map of the middle level on the Des Plaines river, at Joliet, Illinois.

Middle level at Joliet.—The power of the middle level is rented from the state by Mr. Henry Sanger, and sub-let by him. The total power was estimated by Mr. Jenne to be 196 available horse-power under a head of 7 feet of water. The head used at the manufactories is 6½ feet. The power is practically all in use.

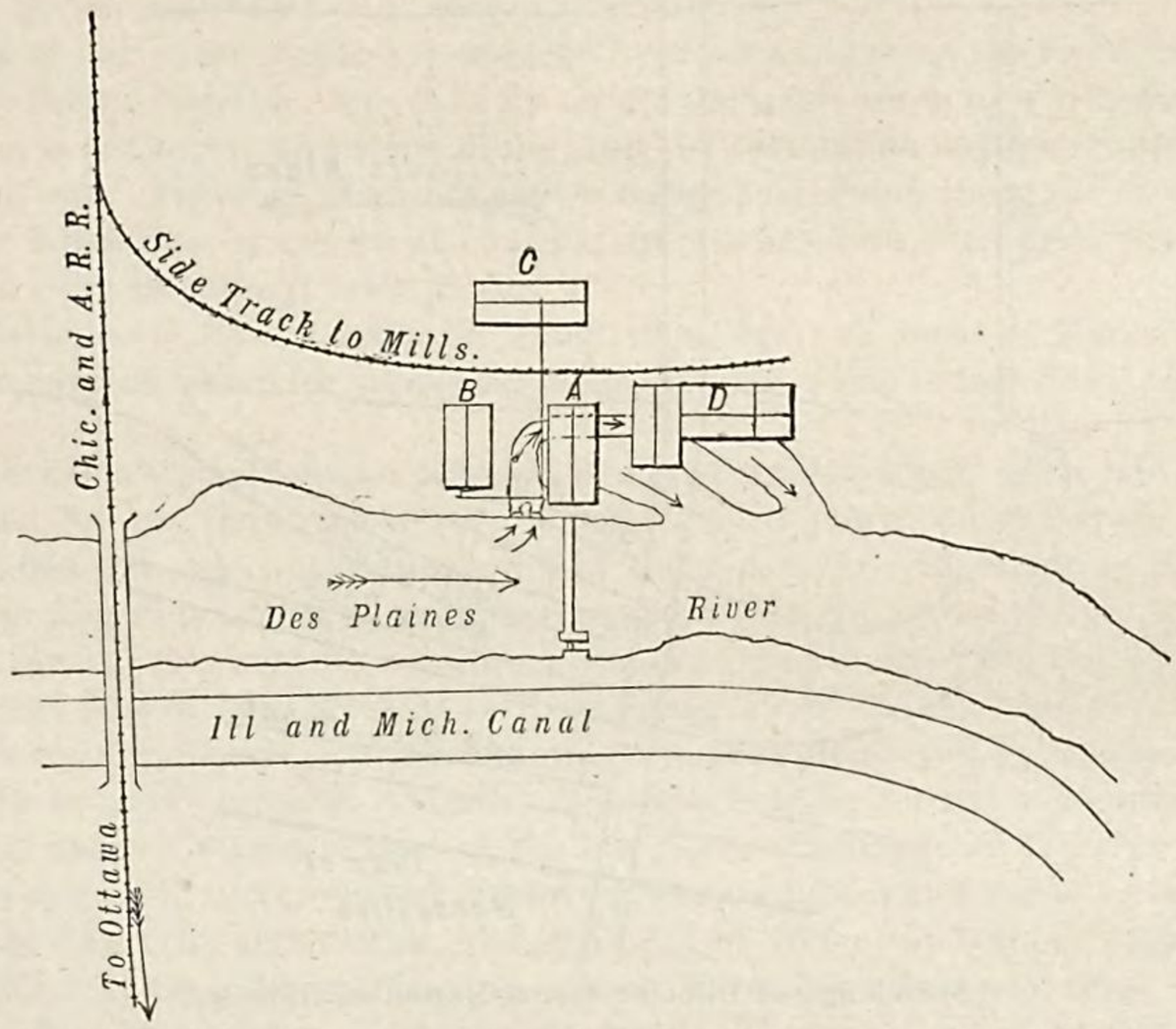
On the right bank, just below the stone bridge which crosses at the dam, are a wire factory and a sash and door factory, taking power from the same wheel-house, which also transmits power by wire rope to an elevator on the left bank of the river, above the bridge. They use altogether 54 horse-power. Below the bridge on the left bank are a foundery and machine shop, using 20 horse-power, and a wire factory, taking 75 horse-power, by shafting from a wheel set at the bulkhead of the foundery.

The masonry dam is about 200 feet long, and curved with a center ordinate of 15 or 20 feet. The bed and banks are of excellent limestone.

Below the dam there is a low rocky island of small size, covered in high water. The lower level backs up, it is claimed, 18 inches upon the wheel of the machine-shop and foundery, and very high stages of river must occasion some difficulty from back-water.

Mills on the canal.—The canal starts from the right bank just above the dam, and skirts the shore of the river. On this there are three manufactories a short distance below the lower dam, described below. They are:

1. A tile company, leasing 60 horse-power; 2. An oatmeal-mill, leasing 100 horse-power; 3. A flouring-mill, leasing 100 horse-power, all under a head of 6 or 7 feet. There is room for many more mills along the canal, but the further use of the water in this way would interfere with the power of the lower level, as is already the case, and will probably not be attempted.



Sketch map of the lower level on the Des Plaines river, at Joliet, Illinois.

Lower level at Joliet.—The water-power at the lower level was developed previously to the opening of the canal, which took place in 1848. The power is owned by Mr. W. J. Adams, and originally included only the natural discharge of the river. By the opening of the canal and the mills at Lockport a large increase was made in the flow of the stream below that place. Mr. Adams claims that the state releases all further right to what water is discharged into the river at Lockport, and cannot divert from the riparian owners below the middle level at Joliet.

The state claims that it can so divert the flow which it artificially introduces into the river from lake Michigan. The erection of the mills on the canal below the middle level was the occasion of a lawsuit, in which the judge of the circuit court decided against Mr. Adams. The case has been appealed.

Mr. Adams' power is very greatly benefited over its original condition by the surplus from the canal. The head of water averages 5 feet 10 inches, and the power is utilized on the left bank by the wire-works establishment of Mr. Adams, using 50 horse-power, and a paper-mill below, leasing 60 horse-power, at an annual rental of $1,100, but using only 40 horse-power. Mr. Adams claims that he has 30 horse-power yet to lease, which would have to be transmitted by cable or shafting.

There is some difficulty, not very serious, during low water, when the canal takes a large part of the flow. Three feet is an extreme rise in the river; with a 2-foot rise the head available is 4 feet.

The dam is a straight stone structure, 200 feet long, 6 feet 10 inches wide at the base, and 3 feet wide at the crest.

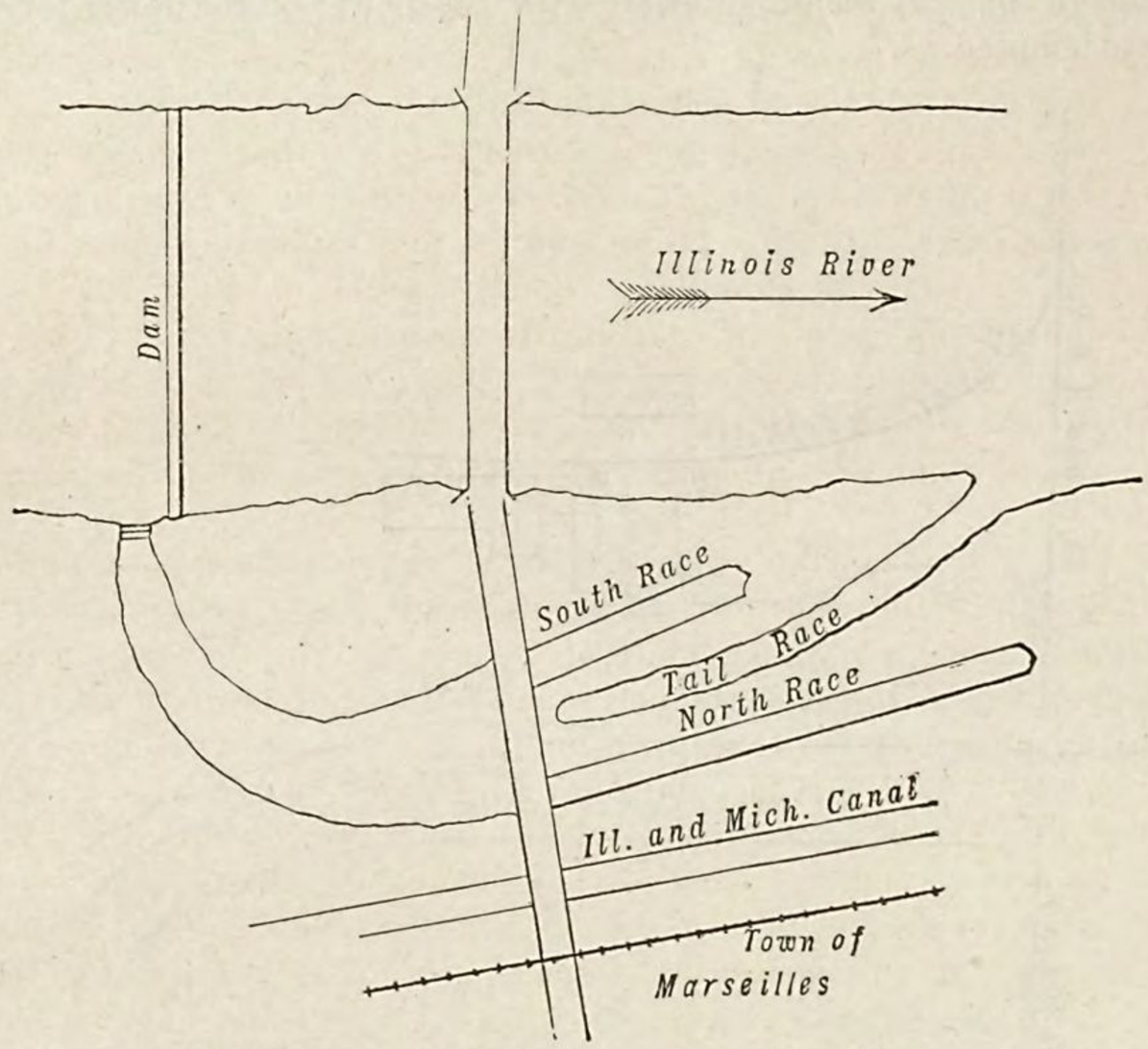
Channahon and Aux Sable.—At these places are the only powers taken from the canal between Joliet and Ottawa. At Channahon is a grist-mill with a head of 7 feet, and leasing power for two runs of stones; and at Aux Sable are a saw-mill and a stave and barrel factory, each leasing 40 horse-power under a head of 6 feet 9 inches.

Unutilized power, Joliet to Marseilles.—There is only one point on the canal between these places at which surplus water is available for power, and that is Morris, 17 miles above Marseilles, where the surplus is probably sufficient to give 75 or 100 horse-power under 10 feet head.

Upon the Des Plaines river there are two available powers below Joliet. The first is 2 miles below the city. By a dam 200 or 250 feet long and a moderate amount of levee, on a good limestone bed and banks, it is claimed that 6 feet head can be obtained without backing upon the wheels of the lower level at Joliet. The facilities are good for building a race.

Two and one-half miles below Joliet is Joliet lake, an expansion of the river, 6 miles long and from 1 to 1½ mile wide. The second power is at the foot of the lake, where there are rapids, and a head of at least 6 feet available. The site is 1 mile from the railroad; the bed and banks are of rock, the latter 8 or 10 feet high at the river, and affording good facilities for constructing races. There would be required about 200 feet of dam and 150 feet of levee on each side.

From here down to the junction with the Kankakee there are no powers of value upon the Des Plaines river, and the same is true of the Illinois river, down to Marseilles, which can boast the only developed water-power on the stream.



Sketch map of Illinois river, at Marseilles, Illinois.

Marseilles.—The town of Marseilles has 1,822 inhabitants, and is situated upon the right or north bank of the Illinois river, 27 miles below the junction of the Kankakee and the Des Plaines. The railroad between Chicago and Rock Island passes through the town, as also does the canal.

The north rim-bank of the river is about 10 feet high, and back from this stretches a level flat for a quarter or half a mile, upon which the town is laid out. The land upon the south side of the river appears much the same, but somewhat higher.

The facilities are excellent for utilizing the full power. All now used is taken on the north bank, between the canal and the river. A timber dam 700 or 800 feet long extends from bank to bank and backs the water into a race, which divides below the bridge into two, a "north head-race", and a "south head-race", the latter being the shorter of the two.

There are five manufactories on the north race and three upon the south race. The head is approximately 9 feet at all, but at the end of the race it is about 10 feet. The tail-race is excavated between the two head-races.

The power was developed by a hydraulic company, which started with a capital of $500,000, and afterward issued bonds for $85,000 more. The company failed to pay either interest or principal, and so the bondholders placed the matter in the hands of a receiver, Mr. J. N. Chappelle, of Marseilles. It is likely that the property will all come under the control of the bondholders.

The total power in use in the spring of 1881 was 490 horse-power, distributed as follows, in passing down stream:

North head-race.	Horse-power.
Oatmeal-mill	120
Agricultural implements	60
Pearl-barley mill	35
Paper-mill	100
Agricultural implements	50

South head-race.	Horse-power.
Paper-mill	60
Paper-mill	65
A paper-mill in process of erection with a contemplated power of 125 horse-power.	

The paper-mill which was under construction in the spring of 1881 had the privilege of leasing 400 horse-power at the rate of $10 per horse-power.

Only a small part of the total power is in use. It is considered that 3,000 horse power are available for ten months of the year, but in August and September the river is usually too low to furnish that amount. There is an old cofferdam at the head of the race, much obstructing the flow, but it is felt that if that were removed from 1,000

to 1,500 more horse-power than is now in use could be supplied with the present races, and there is no reason why these should not be made more extensive. There are a number of vacant lots upon the races as they now exist. The south race runs out to the river bank, but the north race could readily be continued down-stream for a considerable distance.

When the improvement of the river at Ottawa, which will be shortly described, was made, the Marseilles company, fearing that the water would be set back upon its wheels, ran a small race half a mile down the end of the north race, and built there an organ factory with a head of 18 feet, not now running. It is said that the Ottawa level backed up about 8 inches upon the wheel of the organ factory.

The Marseilles pond now backs up about 22 miles, but it is thought that the dam could be raised 2 feet higher if required. This would give a head of 11 or 12 feet at the mills.

There is no difficulty of any consequence experienced from back water, as the river does not rise over 6 feet at this place. Occasionally there is trouble from cake-ice on the dam, the apron of which was badly broken up in the spring of 1881. The dam is of timber, with stone filling, and the foundation rock generally of good quality, but soft in places, where it wears out. There is litigation now pending concerning the right of certain lessees to sublet. They supply some other industries by means of shafting from wheels on their own premises, and the company claims that they have no right to subrent their power.

Unutilized power, Marseilles to Ottawa.—On the canal there are two locks at Marseilles, having a total lift of 16.7 feet, but there is no surplus water for supplying mills, and the same is true down to Ottawa, where the Fox river feeder enters.

Upon the Illinois, between Marseilles and Ottawa, is a good undeveloped water-power. About the year 1870 a company was organized for the improvement of an undeveloped power on the river at that place, the city of Ottawa subscribing $60,000. A mile above the mouth of the Fox river is an island in the middle of the channel. A dam was thrown across from this island to both shores, and a race cut across the point of land to the Fox river, which also had a dam thrown across near its mouth. From the right bank of the Fox river it was the intention to run a race down, taking the flow of both streams and obtaining about 16 feet head of water. The scheme was a good one, but the dams were very poorly constructed and were soon destroyed by the floods and ice, the company became bankrupt, and the property remains unused. It is now held by a trust company of Newark, New Jersey.

Since the canal feeder takes the greater part of the low-water discharge of the Fox river, it would hardly be profitable to include that stream in any proposed improvement now, but a dam could be thrown over the Illinois at the old site and a race run down the north bank, giving a head of 16 feet and about 3,500 theoretical horse-power during ordinary low water. Taking the statement made at Marseilles as a basis, there is 5,300 theoretical horse-power available at this place during ten months of the year. To get a head of 16 feet it would be necessary to back the water up nearly upon the Marseilles power, 6 miles above.

At one time it was proposed to redevelop this power and utilize a portion of it for a flint-glass factory. The incoherent Saint Peter's sandstone furnishes a deposit near Ottawa of remarkably pure white quartz sand, which is extensively shipped for glass making. Freighted to Pittsburgh, Pennsylvania, it costs $6 or $7 per ton, while it can be delivered at Ottawa for 65 cents per ton.

Ottawa.—Ottawa has 8,000 inhabitants, and is situated on the right bank of the Illinois, just below the mouth of the Fox river. The water-power is obtained from the Fox river by means of the Fox River feeder of the canal.

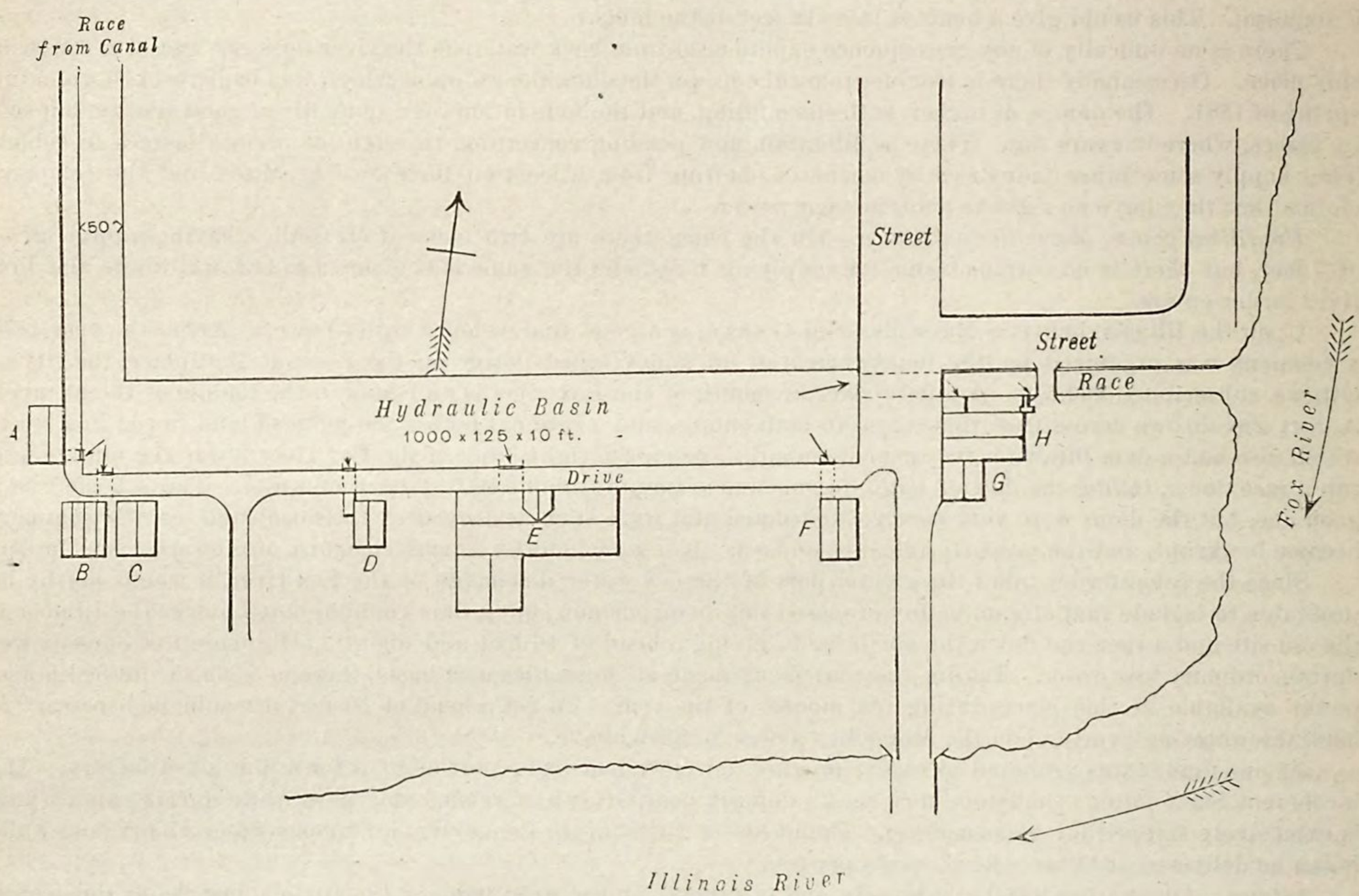
Four miles from Ottawa and a third of a mile above the village of Dayton, a state dam is thrown across the Fox river, and the flow partly diverted into the feeder, about 50 feet wide, which enters the canal at Ottawa. Below the entrance of the feeder, a race about 50 feet wide conducts the water from the left bank of the canal to a hydraulic basin 1,000 feet long, 125 feet wide, and 10 feet deep, lying parallel with the river and several hundred feet away from the bank. On the east the race is terminated by the street leading to the highway bridge, but a small race, 15 or 20 feet wide, passes under the street and extends east 300 feet or more to the bluff at the mouth of the Fox river, where the water escapes through a weir and falls over the rocks to the river below. Along the river side of the basin and race are located the manufactories, discharging their water through tail-races into the Illinois. The river bank of the basin is built up of earth, with a well constructed inside wall of masonry, and serves as a drive-way for access to the various buildings. The flumes for the wheels pass under the drive-way.

Nature of ownership.—The power is controlled by the La Salle County Manufacturing Company, chartered about the year 1850. The company obtained possession of the power in this way: A Mr. Green owned the right shore of the Fox river at Dayton and one half the flow of the river. When the state built the "feeder", Mr. Green surrendered half his share, or one-quarter of the flow of the river, for canal purposes, the state maintaining the feeder and dam, and furnishing him his one quarter flow free of charge. Then the La Salle County Manufacturing Company obtained the one-half flow of the river unused, and the surplus from the feeder over what was required for working the canal, paying now for the latter $750 rent per year.

The company leases building-lots, and leases its power in divisions called "runs", a run being the power necessary to drive one run of stone and its machinery, and equivalent, as nearly as can be ascertained, to about 18 horse-power. It is not considered by the company that a total of more than thirty runs can be supplied, although

the available head is from 33 to 35 feet. The terms of lease are various, but the price averages from $200 to $250 per run per annum. The powers are distinguished as first-, second-, and third-class runs. The state has a first right to the water, and the canal must be kept full even if the mills have to shut down.

First-class runs are entitled to power as long as there is any surplus from the feeder, while second-class runs are required to shut down if there is not more than enough surplus from the feeder to turn all the first-class, and so on with the third-class. There are six first-class, nine second-class, and fifteen third-class runs. The company has no right to convert any first class into second-class runs, but when a lease expires it can transfer a run of one class from one locality to another, always keeping the total number the same.



Sketch map of mills and hydraulic basin, at Ottawa, Illinois.

The agreement has been made in the leases that the company shall not be responsible for failure of the power provided it maintains the race and basin up to a limit of thirty days per year. If the manufactories have to shut down beyond that time, then a proportionate amount is deducted from the rent.

There are eight or ten runs remaining to be disposed of, two of them first-class runs. Abundance of space yet remains on the basin and the race for the complete development of the power. When there is a fair stage of water the running of all the mills at full power has no effect upon the head, and ordinarily there could be much more power used than is now the case.

The manufactories using the power are as follows, proceeding from the west to the east end of the basin; the powers stated are only approximate, owing to the difficulty of obtaining satisfactory information:

1. A flouring-mill, now closed; it had three runs, under a head of 18 feet.
2. A small flouring-mill, now closed.
3. A brick and tile manufactory, using 30 horse power, under a head of 23 feet.
4. A box factory, belonging to the starch factory, and using 80 horse-power, under a head of 23 feet.
5. A starch factory, using 175 horse-power, under a head of 23 feet.
6. A sash and blind factory, using 40 horse-power, under a head of 21 feet.
7. A flouring-mill, using about 80 horse-power, under a head of 33 feet.

No. 5 leases power amounting to ten runs. No. 7 has the finest power, controlling six runs, of which four are first-class.

East of No. 7, along the small race, were two or three mills, which were burnt down about 1875. At the extreme end of the race was a flouring-mill leasing three runs, one of them first-class.

The water-power may be considered a nearly constant one, the number of days when the mills shut down not averaging over fifteen or twenty for the entire year. There are three ordinary causes for the diminution or entire failure of the power:

First. About the middle of November, and again about the 1st of April, the water is shut off at Dayton, and the feeder is cleaned out, an operation that takes four or five days at each time, and during it all the mills are shut down.

Second. Sometimes the water is so low that the mills have to shut down entirely or in part; for they can only use the surplus after the canal is supplied. This affects the third and second classes, and then the first class. It very rarely occurs that there is not enough water for the six first-class runs, but when it does so occur, then the manufacturers agree upon an equitable division of the time of running. Sometimes in summer the water is low and the mills are impeded, but this is quite as liable to occur in winter, when no boats are navigating the canal. The feeder is long, and if ice becomes very thick the flow is much impeded; moreover, the flow of the river is often small in winter. In the severe winter of 1880–'81 there was a break in the feeder, and, the water being shut off, the ice fell to the bottom and froze fast; then when the water was turned on more ice was added to that below, until there was little space for the flow, and the mills were very seriously impeded.

Third. During very high water in the river it backs up into the tail-races, and tends to diminish the power, but never destroys it.

The maximum head available when the river is at an ordinary stage is 34 or 35 feet, and as 18 feet is a very extraordinary rise upon the Illinois at this place, and 8 feet a large rise on the Fox, where not affected by the Illinois, it is evident that the difficulty from this cause cannot be very great.

One advantage of this water-power is that the mills are entirely away from danger of floating ice, and there is no local responsibility for maintaining the dam, which is under the control of the state. The banks of the river about the basin are rocky, and furnish excellent foundations for buildings.

Water-power at the "Canal cut".—There is one power at Ottawa owned by the La Salle County Manufacturing Company to which no allusion has yet been made. It is located on the main canal, where the race connects it with the hydraulic basin. The canal is above the general level there, and empties into the race by a lock with a lift of 5 or 6 feet. There are two manufactories located on the east side of the race, and using the head at the lock. One is a plow factory leasing one run, and the other a chair factory leasing two runs. The water from the wheels is delivered into the race. It is possible to further develop the power at this place, but far preferable sites can be obtained at the basin.

Unutilized power, from Ottawa to the Mississippi.—It has been already stated that there are no utilized powers on the canal below Ottawa. At Ottawa there would be available power were there any surplus water, but the La Salle Manufacturing Company is entitled to all there is. At La Salle, near the terminus of the canal, there is surplus water and a good site, with a head of 10 or 12 feet.

Upon the Illinois below Ottawa there is no available power. At Utica, 10 miles below Ottawa, there are rapids, but one bank is very low, and the place was described as being so ill adapted for development that it was not visited.

The total fall in the river from La Salle to its mouth, a distance of 230 miles, is only 33 feet, and this would preclude all idea of available power. It is true that there are two government dams already existing, with a lift of about 7 feet at each, and two more are proposed, but they do not offer any available water powers. In the first place, it is extremely doubtful if the United States government would allow the use of the power, the policy being to avoid all connection where possible with private interests, and past experience shows the soundness of this principle. In the second place, there are grave disadvantages and difficulties to be met in utilizing the power, even if permission were granted. Major Lydecker, of the United States engineers, stationed at Chicago, very kindly exhibited profiles showing that for much of the year there would be no head obtainable at the dams. The profile shows that for four or five months of the year the stage of the river is such that the level is practically the same above and below the Copperas Creek dam, and boats pass directly over its crest. It is thought that the difficulty would be even greater at the other dams.

When the state had finished the Henry dam, advertisements were made for bids for the lease of the water-power, but the report is that no bids were offered because of its unreliable character.

In low water, when there would be an available head, the government would probably not allow the water to be drawn below the crest of the dam, and this might occasion further difficulty. It is equally improbable that the government will allow the use of power from the proposed Hennepin canal and Dixon feeder if they are constructed, unless in special cases, in which prior rights exist.

TRIBUTARIES OF THE ILLINOIS.

KANKAKEE RIVER.

General description.—The Des Plaines, a tributary of the Illinois, has already been described, and as there are no streams entering it of any importance, the Kankakee comes next in order. After the Sangamon this is the largest in extent of area drained of all the branches of the Illinois. Thirty-two hundred of its 5,300 square miles are within Indiana, and of its length of about 140 miles, approximately 85 miles are located in that state.

The general course of the stream is southwest to the junction with its large tributary, the Iroquois, and then it turns northwest to where it joins with the Des Plaines to form the Illinois. The character of the river is very different in its upper and its lower portions.

The basin is generally level, but near the state line a ledge of limestone runs across the valley, and has so prevented the wearing down of the bed that a very large part of the drainage area in Indiana is one vast swamp, with wooded knolls and ridges rising here and there above it. In dry seasons the roads across this section are traveled, but when there is much rain they are well nigh impassible, and the river winds about with a scarcely distinguishable channel. Some of the higher land is cultivated, but the inhabitants are very scattered.

In Illinois the bed is not cut deep below the surface. The hills, or rather bluffs, are not high, but are well wooded, and the valley itself is a shifting scene of green meadow, thicket, and grove, down to the edge of the river.

It will be readily understood that the available water-power of the Kankakee is in the 55 miles (map measurement) from the state line to the mouth. The total descent between those two points is about 135 feet, and much of it occurs so as to be available. The bed is largely rock, and, with the banks, is suitable for the building of dams. The rim-banks are generally high enough to prevent extensive flooding of land. There are several dams already built, and a number of manufactories now using the power of the river.

Upon the upper waters there is slight fall, and no water-power of any account, except on the small tributaries.

The Yellow river, which joins the main stream near the source, is of about the same size, and, rising in the high land south of the swamps, has some available water-powers.

Flow, etc.—Notice has already been taken of the important bearing the swamps of the Kankakee have upon its character as regards steadiness of flow, making it in that respect the best water-power stream of the Illinois basin. The "ordinary low discharge" is about 1,300 cubic feet per second, but if it were not for the swamps the amount would probably fall to nearly half as much.

The local increase in the annual rainfall at the southern end of lake Michigan occurs within the Kankakee basin, but chiefly during spring and summer, while through the remaining seasons of the year the precipitation is rather less than on the other rivers of the Illinois basin. This greater inequality in the distribution of the rainfall throughout the year makes the swamps of special value in maintaining the flow. The lowest water is usually during September and October, the highest from late winter into April. Ordinary summer freshets take from 10 to 14 days to rise and disappear between ordinary stages of the river, and this below the mouth of the Iroquois, which, although it rises in the swamp region, drains a much greater proportion of dry prairie land, and is a comparatively "flashy" stream. This river is of about half the size of the Kankakee above the junction. Its freshets rise sooner, and pass off before those on the main river. The ordinary rise in the Kankakee is from 3 to 5 feet, but an extraordinary rise at Wilmington has reached 9 feet.

The swamps are thought to be gradually drying up, but not enough thus far to destroy their value in maintaining the flow. The proprietor of a large portion of the land once meditated cutting through the natural dam of rock and draining the swamp; this plan was abandoned, but has lately been agitated again.

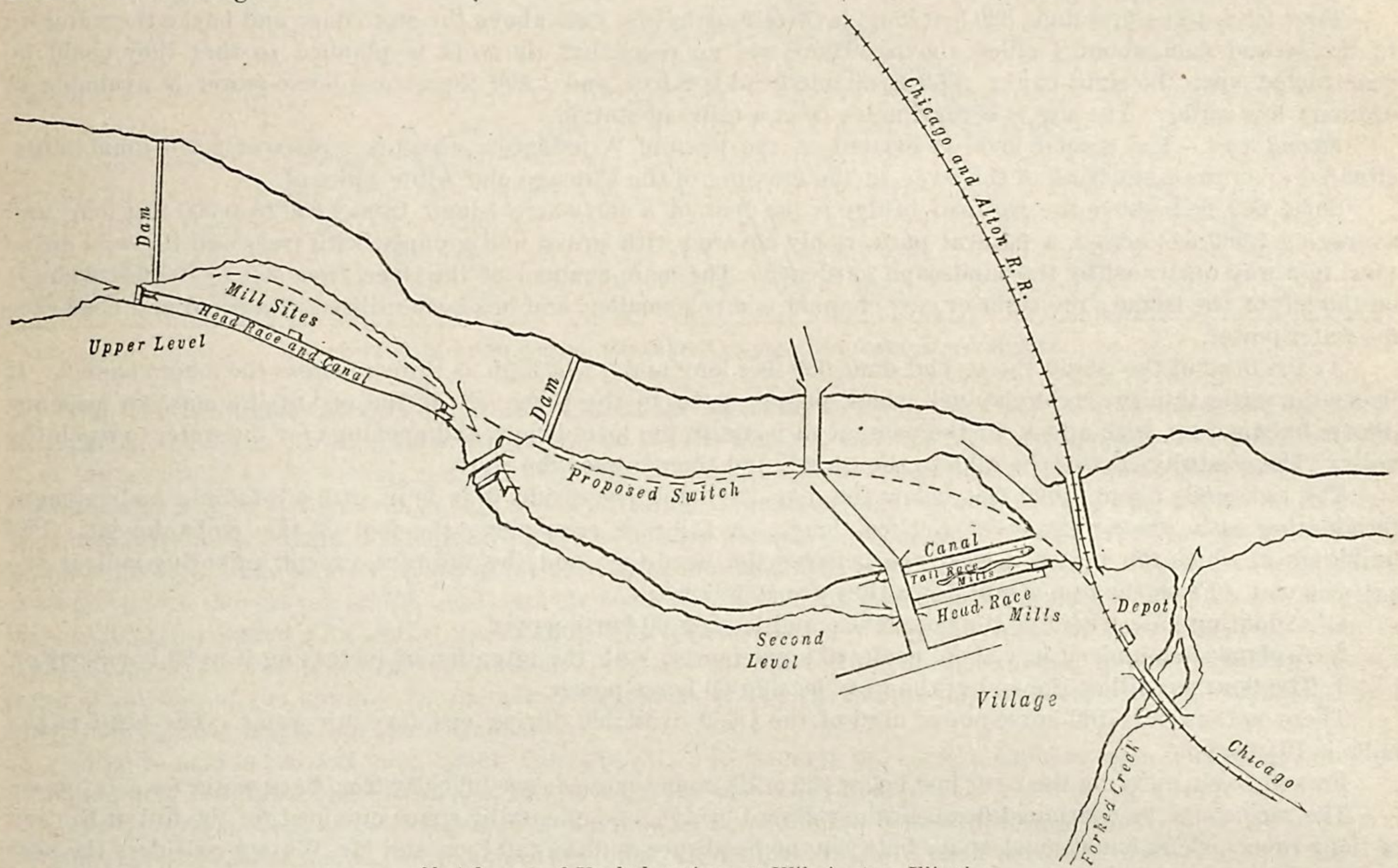
The Kankakee forms one of the few cases in which the cultivation and draining of the land is thought to better the water-powers; it brings into the river water which would otherwise have remained stagnant until evaporated.

While the swamp is a great regulator of the river, it cannot be always depended upon; sometimes it holds the waters fast, and the powers below have to suffer. If the fall rains are light and are followed by a severe winter, the swamps freeze so solid that little if any water escapes to feed the river, and the flow is sometimes insufficient even for the few mills now using the power. Fortunately difficulty from this cause is rare. A manufacturer familiar with the river for many years said that the only two years that he knew of, in which very serious difficulty occurred from this cause, were 1864–'65 and 1880–'81.

Navigation.—Being a large stream, extending through fertile country, attention has naturally turned to the improvement of the navigation of the Kankakee. A company of capitalists obtained a charter from the state of Illinois to improve the river for navigation and water-power. The Kankakee Company built three dams, and, in connection with the feeder of the Illinois and Michigan canal, has established slack-water navigation for about 20 miles from the mouth. Above that distance nothing has been done. The navigation is inconsiderable, but the improvement seems to have had an important effect in modifying the railroad rates for freight from the surrounding country. It is claimed by the state that the company has not made all the improvement required within the time specified, and that its rights are forfeited. The matter is yet in litigation, but the company is left in a rather unsatisfactory condition regarding its water-powers, which are more important to it than the navigation. There is

some hesitation in starting a manufactory upon a power whose ownership is uncertain. The endeavor has been made to have the United States government take the navigation in hand, the Kankakee Company offering to sell all but its water lots and power for $300,000, but the United States engineer reported unfavorably upon the scheme. It is claimed that with a very little dredging a natural navigable course, 7½ feet deep, can be obtained for nearly 100 miles through the swamp region. It is thought possible to run a canal across the summit to the Wabash river, and so form a route to lake Erie, but it would be difficult to feed the summit level, and there are other disadvantages in the way.

Water-power localities.—There are only four places on the entire river at which water-power is in actual use. These are Waldron, 35 miles from the mouth and just above the mouth of the Iroquois; Kankakee, 7 miles below Waldron; Wilmington, 21 miles below Kankakee and about 10 miles from the mouth of the river; and a power 1⅓ mile above Wilmington.



Sketch map of Kankakee river, at Wilmington, Illinois.

The two dams at Wilmington are owned by the Kankakee Company, which also has a dam 4 miles below Wilmington, although no power is utilized from it. Three-quarters of a mile below this dam is the state dam, for turning the water into the Kankakee feeder.

At Momence, 48 miles from the mouth of the river and about 7 miles from the state line, are the remnants of two dams and the ruins of a flouring-mill. This is the extent of the development of the powers of the river.

The Kankakee Company does not appear to lay any claim now to the powers above the three dams, and Mr. E. S. Waters, the engineer of the company, stated that he did not think any objection would be raised to the further development of the river above.

Powers of the Kankakee Company.—Though the finest improvements on the river belong to this company, the amount of power yet in use is comparatively small.

Everything is in readiness for manufacturers to build their bulkheads and turn the water upon their wheels; a large amount of power stands waiting, and apparently nothing but the legal difficulties of the company can deter manufacturers from availing themselves of it; nor does this seem a sufficient reason, for while courts may decide, and property change hands, water must run and the powers about Wilmington be of value.

The rate of leasing the power is $10 per year per horse-power, of which half goes to the treasury of the company and half is retained for the maintenance of the works. No arrangements have yet been made for a rebate during low water, as there is flow enough for all the mills now running. The locks, races, and connecting works, at the different levels are all constructed upon the right bank of the river, for convenience in making repairs. All the appointments are of a most thorough character, unusual to find in the development of western water-powers. The different levels controlled by the company will now be discussed in their order from the mouth of the river up.

State dam power.—The state dam, which turns the water into the Illinois and Michigan canal feeder, is about 5 miles above the mouth of the river. The company obtained permission from the state to raise the dam 2 feet, so as to make the navigation channel pass through the feeder, and thus get a head of 9 feet at the dam. A race could readily be built, and use made of the surplus of water that passes through the feeder. This latter amount is 500 cubic feet per second, and it is therefore probable that in very low stages there would be no surplus at all.

From the foot of the dam down to the mouth of the river there is a fall of about 20 feet, and this could be utilized by another dam, but the flow would be very unsteady, from the cause just mentioned. These powers are away from the railroads.

The feeder being under the control of the state, if any power were used from it negotiations would have to be made with the canal commissioners.

Near the lower end of the feeder there is a fall of about 30 feet, and mill-sites are available.

First level.—The first dam, 820 feet long, is three-fourths of a mile above the state dam, and backs the water up to the second dam, about 4 miles above. There are no races, but the work is planned so that they could be constructed upon the right bank. The available head is 8 feet, and 1,300 theoretical horse-power is available in ordinary low water. The site is several miles from a railroad station.

Second level.—The second level is located at the town of Wilmington, which is a place of 2,876 inhabitants, situated upon the right bank of the river, at the crossing of the Chicago and Alton railroad.

Some 600 feet above the railroad bridge is the foot of a forty-acre island, from 4,000 to 5,000 feet long and averaging 1,000 feet across, a natural park, richly covered with grass, and grouped with trees and the wild grape vine, in a way unrivaled by the landscape gardener. The main channel of the river, from 500 to 700 feet wide, is on the left of the island; the right or east channel is much smaller, and has been utilized as a canal and head-race for water-power.

At the head of the island the second dam, 650 feet long and 5 feet high, is thrown across the main channel. It backs the water into the right channel, which passes down to the town. Near the end of it a massive masonry dike is built across, with a lock for the passage of boats to the level below, and openings for the water to reach the mills. The roadway crosses the dike to the island, and then crosses the river.

The race ends about 1,000 feet below the dike. On the river side it is built with a retaining embankment terminating in a waste-weir about 150 feet long. A tail-race runs along the foot of this embankment. The buildings in which the power is used are between the head-race and the tail-race, except a flouring-mill at the extreme end. From the upper mill down they are as follows:

1. A flouring-mill, with five runs of stones, and leasing 60 horse-power.
2. A plane-shop and cutlery-shop, using 40 horse-power, with the intention of increasing it to 80 horse-power.
3. The flouring-mill at the end of the race, leasing 60 horse-power.

There is thus only 160 horse-power used of the 1,650 available during ordinary low water. The head at the mills is 10½ feet.

Forked creek, entering the river just below the mills, sometimes causes difficulty from back-water for a day or so.

The race could be continued down to the railroad bridge, and plenty of space obtained for the full utilization of the power. There is not much space between the head-race and the tail-race, and Mr. Waters considers the best plan to be to place the wheels between the two, and cable the power across the head-race. On the large island there are places above the road where the channel could be tapped and mills supplied with a head varying between 10 and 5 feet.

Near the abutment of the dam are ten fine ates set in masonry, by which the height of water in the race can be controlled to an inch. There is also a lock for the passage of boats.

Third level.—The power of the third level is by far the finest controlled by the company, and is all in order for immediate use.

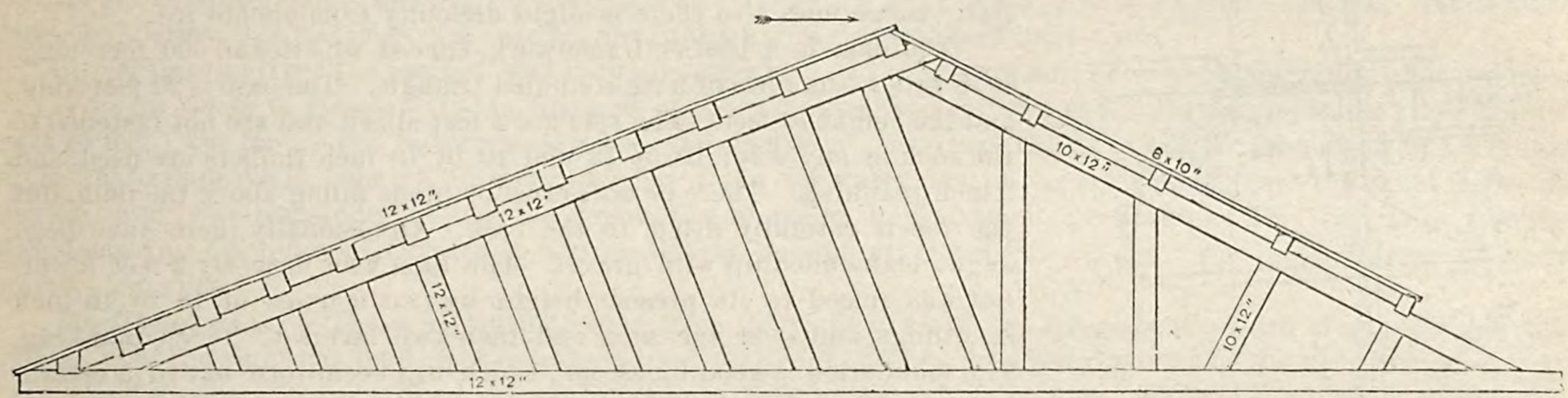
The dam is about 1⅓ mile above Wilmington, and is a very fine structure, 1,000 feet long and 16 feet high, backing the water 12 miles up-stream. The power is taken from a race running down the right bank, 3,000 feet long, 100 feet wide, and 8 feet deep. The average head is 15 feet, and the power is estimated to be 3,000 theoretical horse-power with ordinary low water. The long stretch of deep, still water prevents the formation of any anchor ice. At the head of the race are eight gates, with 7 or 8 feet depth of water on the sills, and after passing through the gates the water flows through four culverts into the race. There is a guard-lock 20 feet wide, closed only in high water. Navigation is through the race, and at its foot is a lock with a lift of 15 feet to the second level. This lift is not exceeded in the state. Beside the lock is an overflow 30 feet wide.

The land through which the race runs slopes slightly to the river, and the race is built up with an embankment on that side. Manufactories would be located just back of this, and receiving their water through it, would discharge into tail-races leading across the flat. The ground is a stratum of limestone thinly covered with soil, and makes excellent foundations. The tail-races have to be partly excavated in the rock. The land slopes gently back on the right-hand side of the race, affording excellent sites for workmen's cottages, should manufacturing requiring many hands be carried on.

There is now only one industry on this level, a straw-paper mill, situated near the center of the length of the race. It uses 80 horse-power, and has a capacity of 10 tons of paper per day. There was in the spring of 1881 some prospect of a cotton factory being built. The Chicago and Alton railroad has agreed to run a side track up the island to the mills when another one is erected.

Dams of the Kankakee Company.—The three dams of the company were constructed by Mr. Waters on the same plan, and hence a description of the upper one will serve for all.

The bed of the river at Wilmington is a gray limestone, full of fossils and cavities, belonging to the Niagara formation. It is the stratum overlying the celebrated Joliet stone, and in descending it is found to become more yellow and white. Although this stone wears and shells out to some extent where the water strikes, it nevertheless makes an excellent foundation for dams.



Section of upper dam of Kankakee Company, Kankakee river, Illinois.

The dam is a timber frame-work 66 feet wide at the base and sharp at the crest. The slope at the back is 2½ to 1, and of the apron 2 to 1. Norway pine is used for the timbers, and oak for the planking. The timbers of the dam proper are 12 by 12 inches, and the planking is 3 inches thick. The frame of the apron is of 10 by 12 inch timbers, with 8 by 10 inch scantlings, and 2-inch planking. The scantlings are notched into the rafters and fastened by ¾-inch drift-bolts. The struts supporting the rafters are placed nearer together toward the toe, where the depth of water is greater. The sets are bolted to the rock by 1½-inch iron drift-bolts, six to each set. The toe of the planking runs down into the gravel to the rock, and in some places cement was used to prevent leaks. The back of the dam is heavily covered with gravel and stone. The mud carried down by the Iroquois river closed the dam so tightly that no air was admitted to the timbers, and dry-rot was setting in. To remedy this the planking was cut away at the foot of the apron. The construction admits of the easy renewal of timbers without tearing the dam open, and a yearly inspection is always made.

The first dam is 820 feet long, 8 feet high, the sets 8 feet apart; the second, 650 feet long, 5 feet high, the sets 10 feet apart; the third, 1,000 feet long, 16 feet high, the sets 6 feet apart.

The river from Wilmington to Kankakee.—There is no available fall between the upper level at Wilmington and Warner, about 12 miles above, but in the succeeding 2 or 3 miles to Altorff there is about 9 feet of natural fall. It is practicable to erect a dam at Warner and obtain a head of about 8 feet.

At Altorff there is an island, and an old dam across the right channel. The dam over the left channel was carried out. There is an old mill at the right bank of the river which does custom work, gaining power by throwing a wing-dam up the left channel in low water. It is of small importance now, although twenty years ago it was a good flouring-mill, with a head of 10 feet. A dam could be built over both channels.

It was the original intention of the Kankakee Company to build a dam at Altorff and run a canal down to Warner through a natural ravine, using it for navigation and water-power, thus obtaining a large head of water.

From Altorff to Kankakee there is a rise of 12.7 feet, according to survey, and power is available, although none is used.

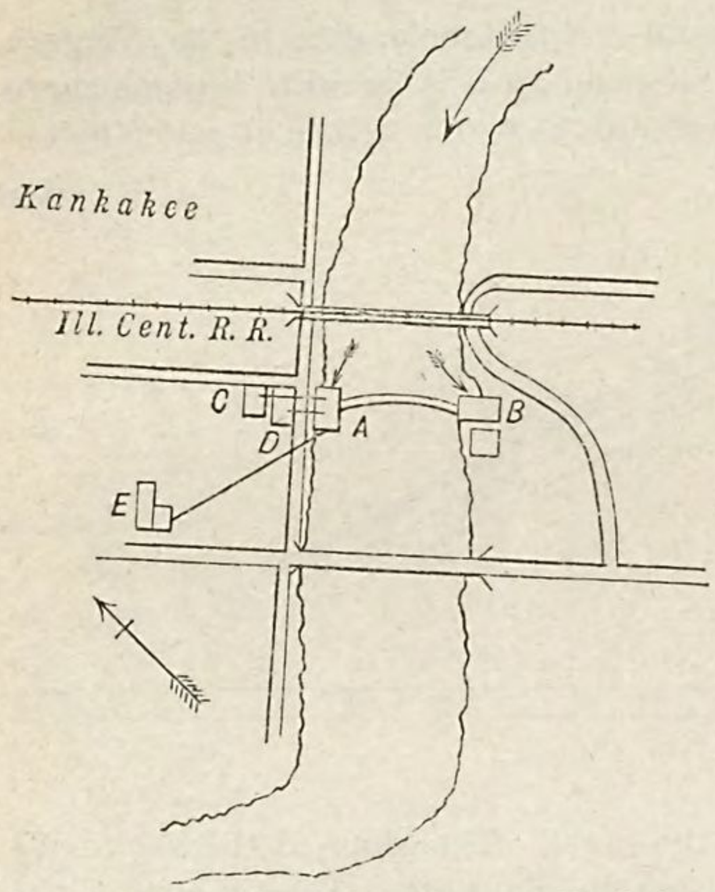
Kankakee.—At Kankakee a dam extends across the river, and five establishments use the power, which is owned by Mr. James McGrew, the proprietor of the flouring-mill. The rim-banks are 10 or 15 feet high, and from them the land slopes gently back. The bed, and the banks for about half their height, are of limestone. There are no races, but excellent facilities for excavating them on each side. The head is 9 feet during low water, and averages 7 or 7½ feet.

At the left abutment of the dam is a paste-board mill, leasing 60 horse-power. At the other extremity of the dam is the flouring-mill, with nine runs of stones, and using 150 horse-power. In the flouring-mill are three other wheels, one transmitting 30 horse-power, by shafting, to a woolen-mill across the street, another transmitting 40 horse-power, by shafting, to a flaxseed-oil mill behind the woolen-mill, and the third furnishing, by means of wire rope, 10 horse-power to a foundery and machine-shop.

All the powers rented now are on an equality, and the proprietor does not feel at liberty to rent any more first-class powers, as in very low stages of the river the full power is used. However, during most seasons, there

would be no difficulty of this kind, and he thinks that 50 per cent. more power could be rented as second-class with advantage. An arrangement is made with the lessees whereby the pond is never drawn down more than 6 inches below the crest of the dam.

No rebate is paid for a stoppage from lack of water of less than forty days per year. This seldom, if ever, occurs. Even with the paper-mill, which has smaller wheels than are used on the other side of the river, the average stoppage is but from twenty to twenty-five days per year, and this is mostly due to back-water.



Sketch map of Kankakee river, at Kankakee, Illinois.

Some distance below the mills the river narrows and causes back-water, so that a 1-foot rise above the dam is equivalent to about 3 feet rise below it, within certain limits. The head sometimes diminishes to 4 feet. Sometimes also there is slight difficulty from anchor ice.

The dam is a timber frame-work, curved up-stream, 500 feet long, with sets in the form of a right-angled triangle. The base is 20 feet wide, and the height 10 feet. The sets are 4 feet apart, and are not fastened to the rock in any way; 10 by 12 and 10 by 10 inch timbers are used, and 2-inch planking. There is no gravel or stone filling above the dam, but the toe is carefully fitted to the rock. Occasionally there have been slight leaks filled up with gravel. The dam was formerly 2 feet lower, but was raised to its present height by two courses of 10 by 10 inch scantlings laid over the sets, and then two layers of 2-inch planking. The foundation is good limestone, which has been worn out to a certain extent by the vertical pitch of the water and ice over the dam, but this action has now ceased.

The river above Kankakee.—The Kankakee pond backs up to the Waldron power, 7 miles above, and extends 1½ mile up the channel of the Iroquois river.

Waldron.—Waldron is a small village just above the mouth of the Iroquois. No visit was made to the place, but information was obtained that there are, on a race, a paper-mill, a custom flouring-mill, with four runs, and an elevator and corn-sheller. The head is 8 or 9 feet. This power is above the Iroquois river, and hence steadier than the powers below the junction. The dam is 400 or 500 feet long. The pond backs up about 5 miles.

From the crest of the Waldron dam to the surface of the river at the state line the rise is 20 feet.

At Momence, which is 10 miles above Waldron, there are the ruins of two old dams and a flouring-mill. The upper dam backed the water to some extent into the swamp region.

A head of about 8 feet is available at Momence, and there is a fall of nearly 13 feet from the river at the lower dam to the Waldron pond. At this place the water-power section ends; we pass into the swamp section, in Indiana, where there is little fall, and no power available.

Tributaries of the Kankakee.—The utilized water-power of the side streams is very small in amount. There are a few mills upon the upper tributaries which flow out of the high land surrounding the swamp, but not more than three or four. On the small brooks entering the river in Illinois there are no mills, and the Iroquois is the only tributary of size.

The Iroquois river.—The Iroquois has not so much fall as the Kankakee, and, as already mentioned, is so unsteady as to materially influence the main river below the junction. The source is in the swamp region of Indiana, scarcely separated from the upper waters of the Kankakee, but most of the basin is level or rolling prairie. In the region about Gilman, in the western part of the basin, are many artesian wells, which add materially to the flow of the river in ordinary low water. The river is considered to be about one-half the size of the Kankakee above the junction.

There are only three mills on the river, one at Sugar Island, about 5 miles from the mouth; one at Texas, about 5 miles below the state line; and one at Rensselaer, in Indiana, near the source. These are grist-mills with two or three runs of stones, under heads of 6 to 7 feet. It is considered that the river will not run a much larger mill to advantage.

THE FOX RIVER.

The Fox river rises in Wisconsin, northwest from Milwaukee, flows south, and then southwest in Illinois, and enters the Illinois river at Ottawa, 35 miles below the mouth of the Kankakee. Its basin is about 130 miles long and averages 20 miles wide; 1,080 square miles are in Wisconsin, and the remainder of its drainage area lies in Illinois, making the total 2,697 square miles. About the upper waters are several lakes, of which Geneva lake and Fox lake are the chief. These serve to a certain extent to regulate the flow, but are not numerous or large enough to make the river a very steady stream. There is no marked difference between the upper and the lower portions of the basin, as in the case of the Kankakee. The country is undulating prairie, with more or less woodland and some swamp.

The low-water discharge of the river is estimated to be 526 cubic feet per second, or 0.195 cubic foot per second per square mile. Those familiar with the stream claim that it has fallen off *one-half* in its low-water volume since the clearing and cultivating of the land and the draining of the swamps. From 15 to 18 feet is an unusual rise in the river near its mouth.

The valley is a quarter of a mile to a mile wide, with sloping bluffs, and the varying woods and grass-land make a pleasing picture. Toward the sources the valley is less deep than below, and the bed is in the drift which covers southern Wisconsin so thickly.

There is considerable fall in the river, but less in Wisconsin than below, where it averages nearly 3 feet per mile. The total fall in the last 47 miles, from Aurora, is 136 feet. In the last 5 miles the descent is about 6 feet per mile. The fall gives rise to a number of water-powers, and of these there are sixteen utilized to give power for fifty-six establishments, using 2,712 horse-power. There is a great variety of industries—flouring- and paper-mills, founderies, tool-factories, wire-works, hardware, carriages, sash and blinds, etc.

In visiting the river the journey was taken up-stream, and the powers will now be considered in that order.

From the mouth to Dayton.—In the distance of about 5 miles from Ottawa to the Dayton mills, the river falls at least 10 feet. So far as the nature of the bed and banks is concerned, this is available for power, but it is not advisable to improve it, because all but a quarter of the low-water flow of the river passes into the canal feeder at Dayton, and the remainder is too inconsiderable to make improvement profitable. The La Salle County Manufacturing Company of Ottawa to a large extent bought up the rights on the river below Dayton, so as to prevent lawsuits.

The Dayton power.—The canal feeder starts from the right bank of the river about a third of a mile above the village. On the right the land rises in a steep bluff for about 50 feet. The left rim-bank of the river is much lower. From the dam down to the village are rapids over a hard variety of Saint Peter sandstone, which also forms the banks to some extent. The space between the feeder and the river gradually widens into a level about 200 feet across at the village. The manufactories are built on this, taking the water from the feeder. A road runs past the mills and up the bluff to the main road and the railroad depot, only a short distance away.

Reference has already been made to the ownership of the power and the removal of three-quarters of the flow to Ottawa by means of the feeder. The remainder is used at Dayton, but in low water the state has the first right of the river, even over this Dayton power. The Dayton mills have the first right after the canal is supplied. The head of water available at the mills is 20 feet, and the total power is estimated to be 228 theoretical horse-power in low water.

There is no serious difficulty from back-water, as the river flows rapidly below the mills. The ordinary rise is 10 feet, though sometimes 15 feet is reached.

The manufactories in their order from the dam are these:

The Dayton Woolen Mills, entitled to three-eighths of the power, of which about 15 horse-power is used by a horse-collar factory next below. Below the collar-factory are a flouring-mill and a tile-factory, in the same building, entitled to three-eighths of the power. Last is the paper-mill, entitled to the lease of one-fourth of the power, but not using it all. All use a head of 18 feet.

There is no surplus power to be disposed of, although the privilege is not in full use.

The dam is 400 or 500 feet long, and is built entirely of 2-inch pine planks, 10 inches wide, laid in a crib-work and spiked together. Then the spaces were filled with drift bowlders, called "hardheads". The stringers were laid 4 feet and the headers 10 feet apart. Iron drift-bolts were let into the rock bed. The dam is faced with 2-inch oak planking. The total cost was $15,000. There is a guard-lock at the entrance to the feeder, and when seen the water was running from 6 to 12 inches deep over the dam, and the lift in the lock was about 4 feet.

From Dayton to Millington.—The Dayton pond sets up-stream about one-half mile. In the 20 miles up to Millington there is no power developed, but some is available. One and a half mile above Dayton is a site where a head of 8 feet can be obtained with a dam about 300 feet long. The bed is hard Saint Peter sandstone, and the banks are good. A race could easily be constructed on either side.

The next available place is at Wedron, 3½ miles above Dayton. There was once a saw-mill with a head of about 6 feet at Wedron, but there is no mill now. There is a good opportunity for a race on the west bank.

From Wedron up to Millington there is not much fall, and there are no specially good sites.

Millington.—At Millington is a dam, partly broken out. The foundation is gravelly in nature. There is a race on each side, and 5 feet head of water. On the east side is a grist-mill with two runs of stones, and on the west side a woolen-mill, unused for the last 10 years.

Yorkville.—The Millington pond backs up 2 miles, and there is no power in the remaining 8 miles to Yorkville. At Yorkville there are a saw-mill, a flouring-mill, and a paper-mill, using the power on the east bank. The head is 5½ feet, and 150 or 200 horse-power is used. There is a surplus, except in very low water.

From Yorkville to Oswego.—The distance from Yorkville to Oswego is 7 miles, and includes a small unimproved power with a head of about 3 feet, 2 miles below Oswego. At Oswego there is a flouring-mill on the right bank, and a saw-mill and furniture factory on the left bank, both at the abutments of the dam.

The average head is 6 feet. The flouring-mill has five runs, and wheels capable of furnishing 90 horse-power. The saw-mill and furniture factory have 60 horse-power. There is much unutilized power and the facilities are excellent for building races on both banks.

There is no difficulty from back-water or from low water, and the only stoppage is for one or two days, owing to anchor-ice. The dam is 390 feet long and 6 feet high. The bed and banks are of limestone.

Montgomery.—The next power available is at Montgomery, about 3 miles above Oswego. At this place there is a dam, and a race upon the right bank. There are here a malt-mill, formerly a sash-factory, with two 48-inch wheels, under a head of 5 feet; a feed-mill, with two runs, and a flouring-mill, with five runs, both under 5½ feet head of water.

Aurora.—The next available power is at Aurora, about 2 miles above. Aurora is a city with 11,825 inhabitants, 47 miles (map measurement) from the mouth of the river.

An island divides the river into two channels, and a dam is thrown across each of these near the head. A race runs down the right bank of the river, and one down the island. The street crosses the river by two bridges at the lower half of the island. On the left bank of the river, immediately at the dam, are the City Flouring Mills, with five runs and a wheel-capacity of 127 horse-power, under a head of 6 or 7 feet. On the island race are a silver-plating establishment, using 30 horse-power, under a head of 6 feet, and Mr. Stolph's woolen-mill, using 50 horse-power, under the same head. On the shore race are the foundery and brass-works of Hoyt Brothers, using about 60 horse-power, under a head of 7 feet. There is very little difficulty experienced with the power in winter, but in summer the water is sometimes below the amount required. The flow in ordinary low water is considered to be 500 cubic feet per second.

The left bank of the river is all built up to the water's edge, and there is no place for a race. There are vacant sites upon both of the existing races. There are the ruins of a mill below the foundery on the shore race. The dams are of timber, amounting to about 500 feet in length. The bed is of limestone.

There is litigation concerning the division of the power. The shore race belongs to the Alexandra estate, and the island race to Mr. Stolph. The Hoyt Brothers own 400 "inches" of water, and the city owns 100 "inches". The remainder is divided between the Alexandra estate, Mr. Stolph, and the City Mills, and about this is the dispute.

North Aurora.—North Aurora is 3½ miles above Aurora, and half way between them is an unimproved power, where there was once a dam, with a head of 5 feet.

At North Aurora there is a flouring-mill, with four 48-inch wheels, under a head of 5 feet, a sash-factory and foundery together, with three 60-inch wheels, and an old, unused saw-mill. The dam is of timber, with a clay and gravel foundation. It is the intention to raise the head to 6½ or 7 feet.

From North Aurora to Batavia.—There is no developed power up to Batavia, about 3½ miles above, but half way between is what is known as the "Stevens power", a good site, with a head of 8 feet available.

At Batavia there is an island, with the main channel on the east. A dam was thrown across this, and the slough on the right closed by a dike.

At the dike is the Batavia Paper-Mill, on the upper part of the island is the Newton Wagon Company, and on the east shore the Challenge flouring-mill. The paper-mill uses 200 horse-power, with a head of 8 feet; the wagon-factory 40 horse-power, under about the same head; and the flouring-mill about 50 horse-power, under a head of 6 or 7 feet. The flouring-mill owns 400 "inches" of water, and of the power belonging to the paper-mill 600 "inches" of water have the first right over all the other powers. Usually, in the fall, there are one or two months when the paper-mill has to run at less than full capacity.

Geneva.—The Geneva power, 2 miles above, is the next on the river. There are four establishments, a grape-sugar mill and a foundery on the right bank, and a grist-mill and a flouring-mill on the left bank. The head is 6 feet.

The foundery owns 300 "inches" of water, the sugar-mill 1,200 "inches", the grist-mill 300 "inches", and the flouring-mill 1,232 "inches". In addition to this there is what is called a "surplus" of about 3,000 "inches", of which the flouring-mill owns one-half, the grist-mill and sugar-mill own 200 "inches", and the remainder is owned by the foundery. Sometimes the mills are troubled with low water.

Saint Charles.—Next is the power at Saint Charles, 2½ miles above. It has two flouring-mills, one of three runs and the other with four runs, a paper-mill using 65 horse-power, and a foundery. The head is from 4 to 6 feet.

Clintonville.—The next available power is at Clintonville, 6 miles above. Formerly there was a dam there with a fall of 6 feet, but it was carried out in the spring of 1881, and the mills have burnt down.

Elgin.—Elgin is 9 miles above Saint Charles, and is somewhat noted as a manufacturing town. There is a race on each side of the river, and thirteen establishments use the power. The dam was carried out in the spring of 1881, but it was thought probable that it would be rebuilt, although there was a tendency to wait until the ice-dealers would agree to bear part of the expense. The average head of water is 7 feet. The power is owned by a hydraulic company, and the distribution was stated by the president to be as follows:

West race.	"Inches."	East race.	"Inches."
Flouring-mill and a machine-shop	1,900	Flouring-mill	1,166
Flouring-mill	1,200	Flouring-mill and a machine-shop	1,150
Foundery	200	Machine-shop	900
Planing-mill	400	Woolen-mill	1,100
Tannery	200	Machine-shop	200
		Wire-works	400
		Agricultural implements	200

All the powers are on an equality, and when the water has been low the manufacturers have divided the time of running in proportion to the amounts owned.

The bed of the river is gravel for a depth of 30 feet, but this is now largely replaced by stone and timber at the site of the dam.

Carpentersville.—There is no power between Elgin and Carpentersville. At this place is a flouring-mill on the east bank, and on the right bank are a foundery and a bolt factory. The dam was carried out in the spring of 1881.

Algonquin.—At Algonquin is the next available power, 6 miles above Carpentersville. There is a dam across the river, and a small flouring-mill on the left bank.

From Algonquin to the source.—The river is less rapid in the upper part of its course, and hence has fewer available powers than below. It averages 150 or 200 feet wide, and flows between gravel and clay banks. In some places it runs close to the bluff, and in others a low flat intervenes. Fox lake is a marshy expansion of the river.

The utilized powers above Algonquin, so far as can be ascertained, are these:

At McHenry are two small flouring-mills.

At Wilmot, in Wisconsin, is a three-run mill with a head of 3 or 4 feet, using 60 horse-power.

Above Wilmot are three flouring- and grist-mills, using 40, 60, and 60 horse-power under heads of 4, 6, and 13 feet, respectively.

Tributaries of the Fox river.—The tributaries of the Fox are necessarily small from the shape of the basin, and have no very important water-power. There are some small mills upon White river, the Nipper-sink, Somanauk creek, Salt creek, and other streams.

White river is the outlet of the clear and beautiful lake Geneva, in Wisconsin, 8 miles long and from one-half to 1 mile wide. It furnishes a remarkably steady power, utilized in three places. At the outlet of the lake are a flouring-mill and oatmeal-mill, with a total of eight runs of stones under a head of 13 feet. All the power is used. Three-quarters of a mile below are a woolen-mill and manufactory of agricultural implements, with a head of 8 feet, and below is a flouring-mill with a head of 10 feet and three runs of stones.

VERMILLION RIVER.

This stream drains 1,413 square miles of undulating prairie and moderately wooded country. It is not of much value for water-power. The only utilization of power is by a flouring-mill, using 45 horse-power, at Pontiac, a small grist-mill below, and zinc-sheet factory, using 10 horse-power, at the mouth. Formerly there were mills at distances of 3, 10, 18, and 23 miles below Pontiac, but now they are all gone.

The banks and the bed of the stream are generally fairly good, and in many places they are of rock. The chief difficulty is the unsteadiness of the flow. The slope is moderate. The mill at Pontiac had a head of 8 feet, and flooded up-stream 2 or 3 miles. The head at the old mills averaged between 7 and 10 feet.

It is said that there is less flow in low water near the mouth of the river than at Pontiac, because of filtration through the bed; also that there are some springs entering just above Pontiac, and that hence the river is more unsteady near the mouth. The draining and cultivating of the land during the last twenty years is thought to have increased the total flow for the year, but to have also added to its irregularity.

The dam at Pontiac was carried out by ice in the spring of 1881. The bed is there a thin cap of shaly limestone, underlaid by soapstone. The soapstone wears out where exposed to the current. There is much difficulty from back-water, and sometimes the wheel cannot run for two or three weeks. Steam is used to some extent. The river at Pontiac is from 60 to 75 feet wide in a good stage, and 1½ foot or 2 feet deep, with a moderate current.

MACKINAW RIVER.

This is a very inferior stream for water-power. Its drainage-basin is 1,182 square miles in extent. According to the census returns there are five flouring- and grist-mills upon the river, using a total of 175 horse-power under heads varying from 5 to 9 feet. The largest power used is 60 horse-power.

The river was better for water-power before the country was cultivated; now there are heavy freshets, and very low stages in late summer. The banks and bed are generally inferior for dams, of a sandy nature, or else of the black loam, which washes easily. With a good stage the river would give power along its lower part for about three runs of stones under a head of 10 feet.

SPOON RIVER.

The Spoon river drains 1,905 square miles in the western portion of the Illinois basin. There are six flouring- and grist-mills on the river, several of them with a small saw-mill attachment. These are all in the last 40 miles above the mouth. They use a total of 249 horse-power under heads varying from 7 to 11 feet, the largest taking 64 horse-power. The names are: London mill, Ellisville mill, Babylon mill, Seville mill, Bernadotte mill, and Duncan's mill, the last about 8 miles from the Illinois. Duncan's mill has about 6 runs, and is the finest mill on the river. Boats can ascend to this mill, which is at the edge of the flats bordering the Illinois.

There was once a scheme started for slack-water navigation to London Mills, but after the sinking of several thousand dollars it was abandoned.

From London Mills down to Bernadotte, 15 or 20 miles from the mouth of the river, the channel is through a light gray sandstone, which is used quite extensively for building. From Bernadotte to Duncan's mill the bed is in a shaly limestone, and below that, in the alluvium of the Illinois flats. Between London and Duncan's mill the banks are generally good for dams.

The river has the usual spring freshets and is very low in summer. Sometimes east of Bushnell, in the lower part of its course, it is not more than 35 feet wide, with a moderate current from 8 to 12 inches deep.

SANGAMON RIVER.

The region of 5,592 square miles drained by this stream was known fifty years ago as the Sangamie region, and the river was called the Sangamie river. The latter divided about 35 miles from the mouth into the North fork, now called Salt river, and the Middle fork, which is now called the Sangamon river. The stream entering about 35 miles above the mouth of Salt river still goes by the name of the South fork.

East of the third principal meridian, which cuts off the eastern third of the basin, is the "bluff country", which is somewhat undulating and elevated; west of it the land is level prairie. Approximately along this line is the "cut-off", so called because the timber here ceases. West of it there is little timber except along the streams, while east there are large bodies of white oak, especially in Macon county. The land is an exceedingly fertile, rich, black loam, especially adapted to corn. Stock-raising is very largely carried on.

There is very little water-power used in the basin. The census returns show a total of 235 horse-power used by fourteen grist- and saw-mills. The heads used vary from 3½ to 12 feet. The largest power used is 30 horse-power under a head of 12 feet. There are three grist-mills and one saw-mill on the main river, using 73 horse-power. On the South fork is one grist-mill using 30 horse-power. The returns credit Salt river with six grist-mills and three saw-mills, using 132 horse-power.

The river is of very little value for water-power, owing to the variation in its flow and the insecure bed and banks. Little if any rock is found along the banks, and in some places the river flows through quicksand. It is about 75 feet wide at Decatur and from 100 to 200 feet wide in the vicinity of Springfield. The rim-banks generally are from 6 to 12 feet high. High water floods the land in some places for 2 or 3 miles in width, but in late summer and fall the flow is very small.

The river was formerly more steady than now, and floods took three or four weeks in rising and disappearing. There were large collections of drift-wood, etc., in the bends, which retarded the flow, and the water running up the courses of the side-streams among the roots and grasses of the swamps was much delayed in its passage to the Illinois. Now the drift-wood is burnt out, and the land drained and largely cleared off. The river-bed is scoured out deeper, owing to the freer passage of the water.

CROOKED CREEK AND MACOUPIN CREEK.

The first drains 1,286 square miles and the second almost exactly 1,000 square miles.

Crooked creek has only two grist-mills, using 28 and 20 horse-power, under heads of 8 and 7 feet, respectively. At one time there were more mills on it, but it is unimportant for power.

Macoupin creek is small, sluggish, and has no utilized power.

EASTERN TRIBUTARIES OF THE MISSISSIPPI, FROM THE ILLINOIS TO THE OHIO.

The only streams of any size in this distance of 213 miles are the Cahokia creek, entering the Mississippi opposite Saint Louis; the Kaskaskia, called the Okaw by the Indians; and the Big Muddy. There is only 107 horse-power in use from the streams in the entire district.

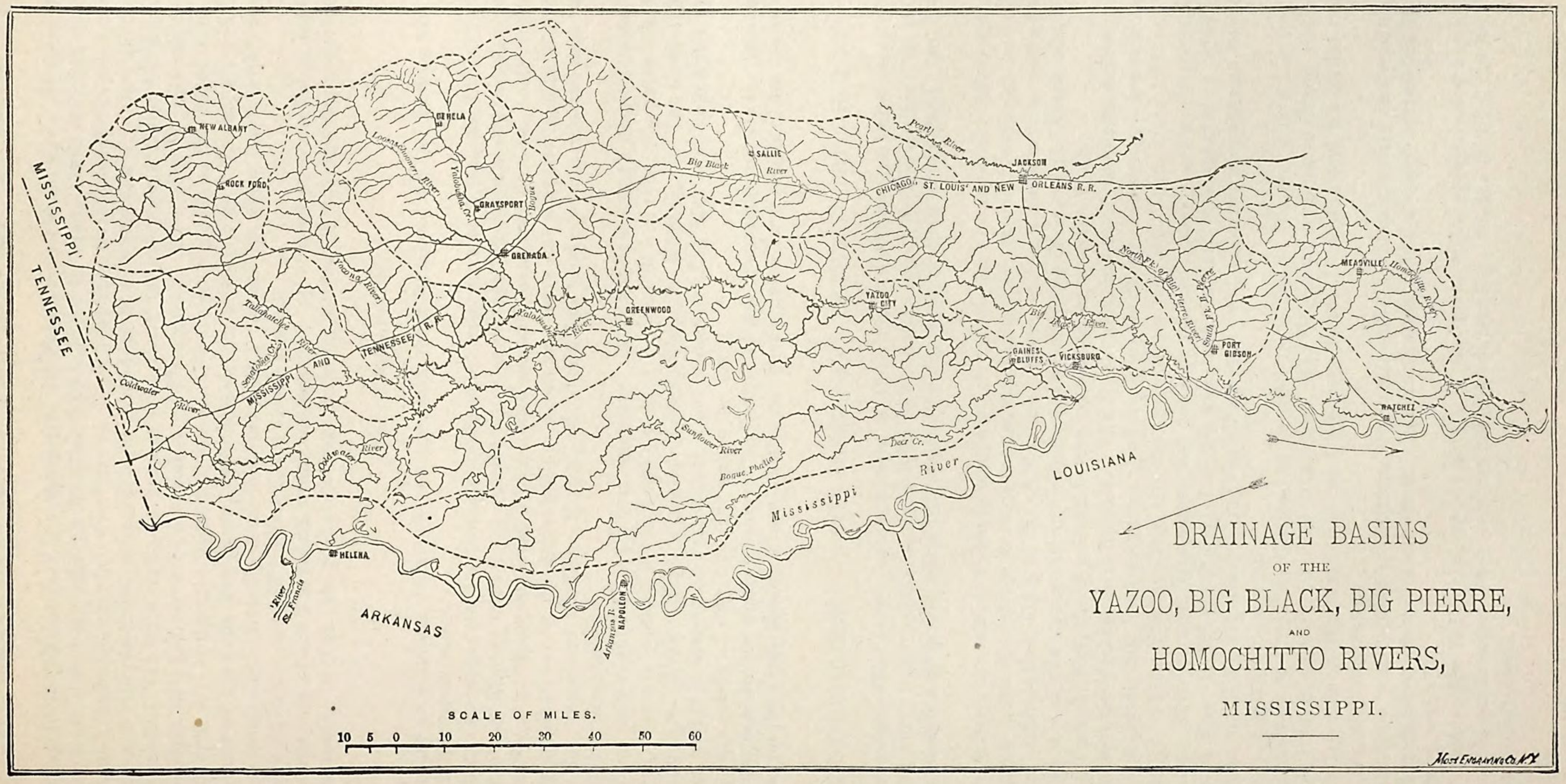
Cahokia creek is a small stream, draining only from 300 to 400 square miles, with no mills upon it, and is of no importance for water-power.

The country drained by the Kaskaskia and the Big Muddy is level or undulating, and the soil is largely "mulatto soil", a yellowish-brown clay. This is well adapted to winter wheat, which is the staple crop, while corn is not so abundantly raised as on the black loam farther north. There is considerable timber, especially in the Big Muddy basin; white oak, poplar, hickory, elm, and sycamore, among others. The black walnut has mostly been cut off. Oak, hickory, and poplar are quite extensively manufactured into lumber.

KASKASKIA RIVER.

The drainage basin of the Kaskaskia measures 5,876 square miles and is 180 miles long, the narrow upper end reaching within 40 miles of the state of Indiana.

There are only two grist-mills on the stream, one using 30 horse-power, under 6 feet head, and the other 12 horse-power, under a head of 4 feet. These are located near the central part of its course.


DRAINAGE BASINS
OF THE
YAZOO, BIG BLACK, BIG PIERRE,
AND
HOMOCHITTO RIVERS,
MISSISSIPPI.
SCALE OF MILES.
10 5 0 10 20 30 40 50 60
MISSISSIPPI
TENNESSEE
ARKANSAS
LOUISIANA
Mississippi River
CHICAGO, ST. LOUIS AND NEW ORLEANS R. R.
MISSISSIPPI AND TENNESSEE R. R.
NEW ALBANY
ROCK FORD
GENELA
GRAYSPORT
GRENADA
GREENWOOD
SALLIE
JACKSON
YAZOO CITY
GAINES BLUFFS
VICKSBURG
PORT GIBSON
MEADVILLE
WATCHEZ
HELENA
NAPOLEON
Pearl River
Big Black River
Yazoo River
Yalobusha River
Tallahatchie River
Coldwater River
Sunflower River
Bogue Phalia
Deer Cr.
North Fk. of Big Pierre River
South Fk. of Big Pierre River
Homochitto River
St. Francis River
Arkansas R.
Moss Engraving Co. N.Y.

The river has little descent, and in summer and fall dwindles to a small size. At times it can be crossed dry-shod at Vandalia, about midway between the source and the mouth, where it is 60 or 70 feet wide. Along most of its length the bed and the banks are of clay and gravel, not of very good quality for the location of dams. These causes conspire to make it an undesirable stream for the development of water-power. Notwithstanding, thirty or forty years ago, when there was little capital and few means existed for getting machinery for steam-mills, the river was used from necessity, and had several grist- and saw-mills upon it. A very few of the dams are yet standing.

The most rapid part of the river is for 15 or 20 miles above Shelbyville, on the upper third of the course, and in this distance most of the mills (five or six) were located. In this 15 or 20 miles the bed and the banks are largely of limestone or sandstone. Usually there is a rocky bluff on one side and a lower bank upon the other. Above and below this section the bed and the banks are of soft material.

The only tributary of the Kaskaskia which can boast of any utilized power is Shoal creek, the largest branch stream of the basin. It has two grist-mills upon it, using 30 and 35 horse-power, under heads of 8 and 10 feet, respectively.

BIG MUDDY RIVER.

The basin has an elliptical shape, with a major axis about 70 miles long and a minor axis about 50 miles long. Its extent is 2,374 square miles.

Beaucoup creek enters from the north, 25 or 30 miles from the mouth, and the Little Muddy river enters from the same side, about 10 miles farther up. These two streams together drain about the same area as the main river above the junction, and Beaucoup creek drains about one-half more area than the Little Muddy. There is not an industry using water-power in the entire basin. Years ago there was a three-run mill at Blairsville, on the main stream above the junction of the Little Muddy, with 5 or 6 feet head of water, but the dam was frequently carried out and was finally abandoned.

The river has only slight fall and is very unsteady. At Murphysborough, about 6 miles below the junction of Beaucoup creek, where it is about 160 feet wide, with rim-banks 10 feet wide, the water has risen 30 feet, flooding the surrounding flats. Back-water is experienced there from the Mississippi. The discharge becomes very small in dry weather, and it is largely its fluctuations which makes the Big Muddy so unsuitable for water-power. The bed and banks are chiefly of clay, not very secure for dams.

The tributaries share the characteristics of the main stream. Beaucoup creek is the principal one. There is an extensive bend on the Little Muddy where a claim was once entered for a mill-site, but no use was ever made of it.

EASTERN TRIBUTARIES OF THE MISSISSIPPI, BETWEEN THE OHIO AND THE YAZOO.

General remarks.—The large drainage basin of the Ohio, 214,000 square miles in extent, with its immense tributaries and many water-powers, is the subject of a separate report by Mr. Dwight Porter, and now the section engaging attention is a strip 600 miles long, including the western limit of Kentucky and Tennessee and half of Mississippi.

Although so long, the area included is comparatively small, for the water-shed line of the Yazoo basin, such as it is, runs close to the Mississippi through the entire length of the state of Mississippi, and it is only in Tennessee that the region extends to a width of 70 or 80 miles. There, within a distance in a north-and-south direction of about 125 miles, are all the streams of any importance between the Ohio and the Yazoo basin. They are, in order, the Obion, the Forked Deer, the Big Hatchie, the Loosahatchee, and the Wolf.

The Obion and the Forked Deer unite near the Mississippi, and their combined drainage area is 4,306 square miles, nearly equally divided between them. The Big Hatchie rises in Mississippi, and drains 2,726 square miles. The Loosahatchee and the Wolf, uniting, like the two streams just mentioned, drain 1,392 square miles.

The "plateau slope of west Tennessee" has much fertile land, and is especially noted for its timber, which grows to a great size. In 1870 over a third of the wealth of the state was included in this region. Lumbering is a very important industry, especially along the Obion river, and there are many steam saw-mills at work. Oak, cypress, hickory, poplar, etc., are cut.

Along the sources of the rivers the land is elevated from 500 to 700 feet above the sea, and hence the large streams have a total descent of from 300 to 500 feet. The Obion is navigable to Obion station, the North Forked Deer river to Dyersburg, the South Forked Deer river to the Louisville and Nashville railroad, but was once extensively navigated to Jackson.

The Big Hatchie is navigable to Bolivar. Steamers and "keel-boats" carry the produce of the land, except where the railroads have usurped their trade. The navigation is not stopped by the fall in the streams, but by drift-wood, snags, etc.

There is considerable fall in the upper waters of the main streams, and hence water-power. The rainfall averages 48 inches per annum. The rivers are subject to quite high floods; in 1854 the North Forked Deer river rose 24.5 feet at Dyersburg.

Utilized power.—There is a total of 1,690 horse-power used in the entire district, by about 100 establishments. These are grist- and saw-mills, with the exception of one woolen mill and one or two cotton-gins.

The following data are obtained from the census returns:

There are a saw-mill and a grist-mill on the Bayou de Chien, a small stream in Kentucky, each taking 20 horse-power under a head of 8 feet.

On the Obion are twenty-two grist-mills and three saw-mills, using 403 horse-power. The largest power used is 37 horse-power. The heads vary from 4 to 14 feet.

The Forked Deer has twelve grist-mills, one woolen-mill using 3 horse-power, and two saw-mills. The total power used is 234 horse-power, the largest is 30 horse-power, and the heads vary from 4 to 14 feet.

The Big Hatchie has five grist-mills, using 71 horse-power, with heads of from 4 to 7 feet.

The Loosahatchee has three grist-mills, two of 75 horse-power, under heads of 10 and 9 feet, respectively, and one of 25 horse-power, under a head of 7 feet.

The Wolf river has five grist-mills, using 74 horse-power, under heads of from 7 to 20 feet, and the largest power in use is 22 horse-power.

It is not probable that there will ever be any important water-power developments in this region, for the streams are small where the fall is greatest, and where the volume of water is large it flows with a gentle current in a rather low country.

EASTERN TRIBUTARIES OF THE MISSISSIPPI, FROM THE YAZOO TO THE MOUTH.

Drainage system.—All the streams which it is worth while to include under this heading are the Yazoo, the Big Black, the Big Pierre, and the Homochitto. They drain an area of about 19,000 square miles, thus distributed: Yazoo, 12,794; Big Pierre, 1,018; Big Black, 3,406; Homochitto, 1,201.

The region begins about at the northern boundary of the state of Mississippi, and extends 537 miles along the Mississippi river to the mouth of the Homochitto. The distance from the northern boundary of Mississippi to the Gulf is 872 miles. The region starts at the south with a width of 40 or 50 miles, but gradually widens to an extent of 110 miles. The average width of all but the southern third is from 80 to 85 miles. The total length is about 275 miles.

The Yazoo basin includes all the northern portion; then comes the narrow basin of the Big Black, extending for 150 miles along the southeastern side of the Yazoo basin, and then the comparatively small basins of the Big Pierre and the Homochitto.

The Yazoo is formed by the junction of the Tallahatchee and Yalobusha, and flowing into the Tallahatchee is the Coldwater river. These three principal tributary rivers of the Yazoo basin have the following drainage areas: Tallahatchee river, 5,711 square miles; Yalobusha river, 2,137 square miles; Coldwater river, 1,886 square miles.

General description of the country.—The region under discussion is the northwestern third of the state of Mississippi, and may be divided into two parts—the Yazoo bottom and the hill country. In describing the Delta of the Mississippi mention was made of the line of bluffs which mark its eastern limit; how they start from the river bank at the northern boundary of the state, and leave a strip of land from 40 to 60 miles wide, meeting the river again at the mouth of the Yazoo, 385 miles below. Then the bluffs skirt the river into Louisiana, passing east along the north side of lake Pontchartrain.

Between this line of bluffs on the one side and the Mississippi on the other, is the great Yazoo bottom, 170 miles long, and averaging 40 or 50 miles across. It is a vast low alluvial region, of unsurpassed fertility—the seat of great wealth before the civil war. Except a narrow strip along the Mississippi, all drains into the sluggish Yazoo by winding bayous and scarcely-moving streams. Heavy rains fill the rivers, so that with their little fall they can scarcely discharge the water poured into them; and were it not for the levees upon the banks of the Mississippi it would flood nearly the entire tract. This region is, of course, destitute of water-powers.

Back from the line of bluffs is the hill country, rising to its highest altitude along a north-and-south line, somewhat east of the center of the state. The surface is undulating and hilly, but nowhere mountainous. The highest elevation is thought to be about the sources of Pearl river, in the central part of the state, but probably does not exceed 800 feet above the sea. The sources of the large rivers are probably from 600 to 800 feet above the sea.

The highest ridges of the northern part of the state are, of course, between the sources of the Tombigbee on the east, and the Tallahatchee and Yalobusha on the west. The usual elevation of the hills above the minor water-courses is from 30 to 120 feet.

The topography takes its character from erosion in clay, gravel, and sand. The streams, especially the larger ones, have cut out considerable valleys, and flow through bottoms of some extent and fertility. Above the river bottom there is also fertile land, but a very characteristic feature is sand hills, covered with pines, "blackjack," and post oak. There is considerable timber of a better character—yellow pine, oak, hickory, elm, ash, etc.—and then in the southern part of the state is the immense forest of "southern pine", unsurpassed for size and value of timber.

Distribution of the power.—The boundary between the bottom land and the hill country, so far as it serves to define the water-power regions from those destitute of power, may be said to follow the line of bluffs down into Louisiana, and then east along the Gulf.

The rivers of the Mississippi which flow through the hill country have more or less water-power, which ceases as soon as they enter the low lands. A peculiarity of their basins, and, in fact, of the entire state of Mississippi, is that the utilized power is all on the small streams. There are no extensive developments of power—only small mills use it at all. The reason for this is partly lack of demand and of capital, but is also to be found in the nature of the streams themselves.

The rivers, where the volume is sufficient for a large power, have generally little fall, and very inferior banks and bed. The heaviest rainfall of the year is during late winter and spring, and then the streams are greatly swollen by freshets, which, without a rapid descent, would give trouble from back-water. The smaller creeks, on the contrary, are more easily controlled, have a more rapid descent, and are many of them remarkable for their extreme uniformity of flow. Rising among the sand hills, they are fed by never-failing springs, and at all seasons supply a steady power to mills located upon them. There are some cases in which small mills are run by streams almost within a stone's throw of the fountain head from which they spring.

The available powers of Mississippi are thus to be found upon the smaller streams, and not on the main rivers where they have obtained large size, unless in exceptional cases. There is not a large amount of water-power used in the state, and it is distributed among many establishments. According to the census returns, the largest power used is 80 horse-power, by a cotton-mill in the eastern part of the state. The total power used on the tributaries of the Mississippi from the Yazoo basin to the Gulf, inclusive, is not far from 850 horse-power, and of this 719 horse-power is on the tributaries of the Yazoo. The water-power of the state is utilized almost exclusively by flouring- and grist-mills, saw-mills, and cotton-gins, and the first are by far the most prevalent, especially in the Yazoo basin.

THE YAZOO AND ITS TRIBUTARIES.

The Yazoo itself has no water power, as it flows entirely in the bottom lands. It is sluggish and winding; back-water from the Mississippi extends up to Yazoo City, and the river forms a navigable channel throughout its length. The Tallahatchee and Yalobusha, which unite to form the Yazoo, join near Greenwood, in Le Flore county, after the Tallahatchee has meandered many miles south through the bottom lands. Below the junction there are no important streams entering the Yazoo from the hill country; the Big Black takes all the drainage in that direction.

TALLAHATCHEE RIVER.—One thousand eight hundred and eighty-six square miles of the 5,711 drained by this river belong to the Coldwater, which rises near the northern boundary of the state. The sources of the Tallahatchee are in the sandy, pine ridges which form the divide between the Mississippi and the Tombigbee, but most of its course is in a mixed soil of clay and sand.

The river is rather sluggish, with bottoms largely overflowed in high water, but in some places it flows close to the bluffs. Before the Chicago, Saint Louis and New Orleans railroad was built the river was kept open, and navigated, except in low water, up to Wyatt's, near the present line of the railroad, while in high water small boats ascended much farther. Now there is no navigation up the river. At the railroad crossing the river is some 75 feet wide in a good stage of water, with low timbered banks.

The channel is not very changeable, but the banks are badly overflowed, and the stream is not a good one for water-power, except near the sources, where it resembles the tributary creeks. There are four flouring- and grist-mills on the upper part of the river, using a total of 59 horse-power. The lowest is in Marshall county. The small tributaries have a number of mills upon them.

The Puscuss creek, meaning "Baby" creek, is a fine, steady spring stream, and has two flouring-mills and one saw-mill, with a total of 65 horse-power used, under heads of from 16 to 20 feet.

Little and Big Spring creeks are two small brooks with five flouring-mills upon them, using 58 horse-power.

Tippah river has one flouring-mill, using 12 horse-power.

Yocona river.—The Yocona river is the largest tributary next to the Coldwater. It rises near the waters of the Tombigbee, and enters the Yazoo bottom before uniting with the Tallahatchee. At the crossing of the Memphis and Grenada railroad, in the lower part of its course, it is 30 or 40 feet wide, with low banks. It much resembles the Tallahatchee in character, except that its banks are more unstable. At one place a mill fell to ruins owing to the caving of the banks. There is little, if any, available power except on the upper waters and the tributaries, where are some mills.

Coldwater river.—The Coldwater rises west of the center line of the state, flows west to the Yazoo bottom, and then south to its junction with the Tallahatchee. About half its course is in the Yazoo bottom. It is unnavigable, and is unadapted to use for water-power except in its upper portion. In Marshall county, on its upper waters, are three flouring-mills, using 81 horse-power under heads of from 4 to 8 feet, but there is no utilized power below.

YALOBUSHA RIVER.—The Yalobusha has a more nearly westerly course than the Tallahatchee, and unites with it after 25 or 30 miles of passage through the Yazoo bottom. It is navigated in the rainy season to Grenada on the

Chicago, Saint Louis and New Orleans railroad, where it is about 100 feet wide in ordinary stages, with sandy rim-banks from 3 to 5 feet high. The banks and bed are chiefly of a rather sandy clay or gravel, and high water floods far back over the bottoms. The testimony is that it is a sluggish stream, and not adapted for water-powers on this account, and because of the freshets to which it is subject.

At Benela, near the headwaters, is the only mill on the river, a small flouring-mill, using 10 horse-power, under a head of 8 feet, and the one cause of stoppage is back-water when the river is high. As in the case of the Tallahatchee, the best available power is near the source and upon the small tributary streams, which are many of them rapid.

Loosaschoona river.—About 4 miles above Grenada the Loosaschoona river enters from the north. It is longer than the main river above the junction, but drains somewhat less territory. Like the Yalobusha, its available power is mostly at the upper part and on the side streams; but in places the bluffs approach close to the banks, giving available sites. There is only one improved power on the river itself; this is employed by a flouring-mill northwest of Pittsborough, using 16 horse-power under a head of 10 feet. The owner writes that the wheels are frequently drowned for one or two weeks at a time in the high water of winter and spring, owing to the lack of fall below the mill.

THE BIG BLACK, BIG PIERRE, AND HOMOCHITTO RIVERS.

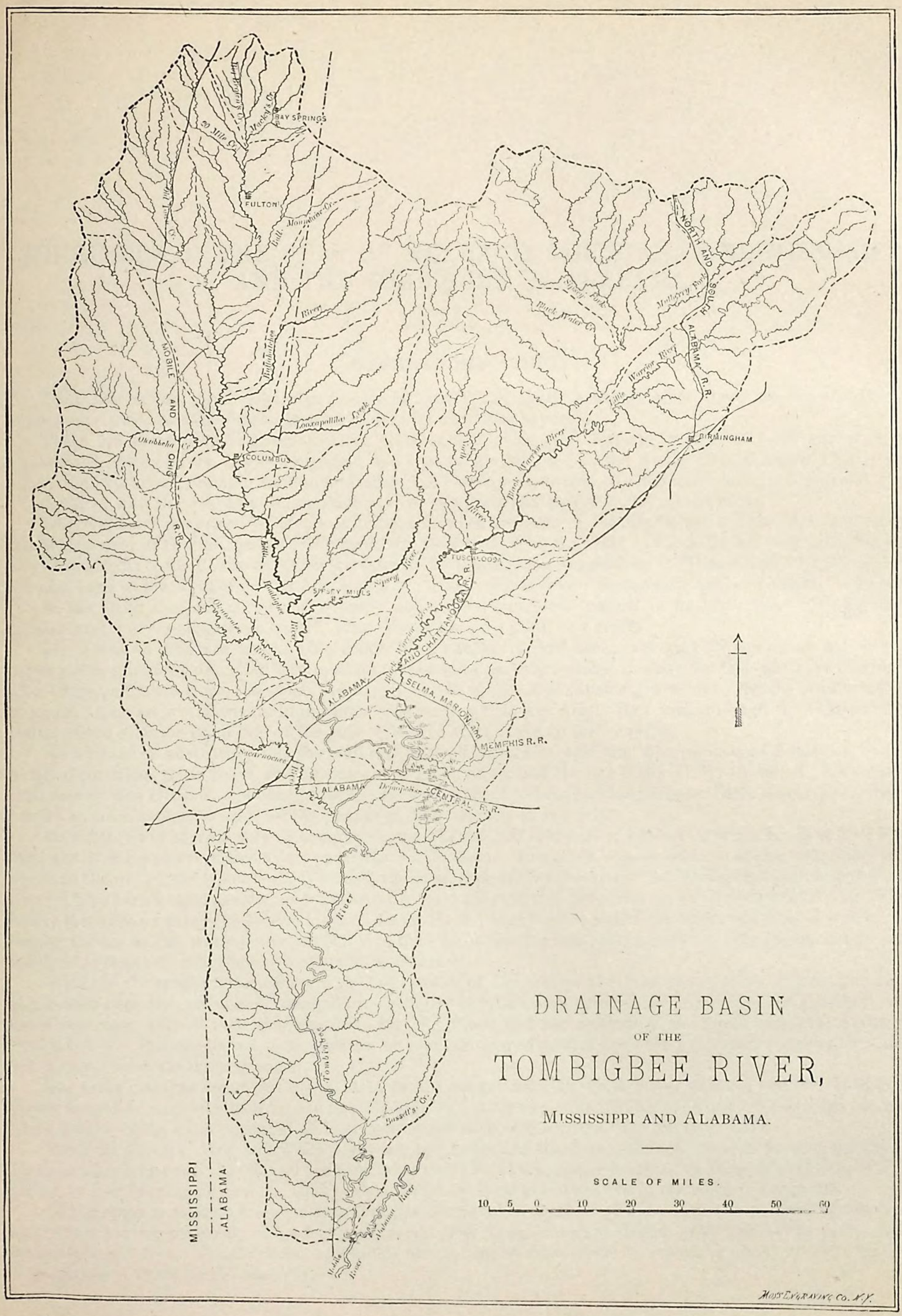
These streams enter the Mississippi where it runs close to the line of bluffs, and hence have no long courses through bottom lands, except such as they have themselves created.

The Big Pierre and the Homochitto may be dismissed with a passing notice, as in the entire region drained by them there is only one small flouring- and grist-mill, using 15 horse-power from a tributary of the Homochitto. They probably have many small undeveloped powers at their upper waters, as do the other rivers of Mississippi.

The Big Black basin is wedged in between the basin of the Pearl on one side and of the Yazoo on the other. It averages about 23 miles wide, and extends northeast as a straight, narrow strip of land for 150 miles, to the divide from the Tombigbee river. The river is scarcely navigable to Way's Bluffs, on the Chicago, Saint Louis and New Orleans railroad. It is sluggish, overflowing its wide bottom lands, and is unfit for water-power except in the upper part.

All the water-power used in the basin is in the northeastern half, with the exception of 26 horse-power taken in Madison county. In Choctaw county there is 41 horse-power used, and in Attala county 46 horse-power, making a total of 113 horse-power.

On the river itself there are five flouring-mills and one saw-mill using water-power, and four of these establishments are in Choctaw county. The total power used from the river is 87 horse-power, the total power of the basin less that in Madison county. One of the flouring-mills in Attala county is credited in the census returns with the use of 40 horse-power under a head of 10 feet, the largest water-power used in the Mississippi basin in the state.


DRAINAGE BASIN
OF THE
TOMBIGBEE RIVER,
MISSISSIPPI AND ALABAMA.
SCALE OF MILES.
10 5 0 10 20 30 40 50 60
MISSISSIPPI
ALABAMA
BAY SPRINGS
FULTON
COLUMBUS
BIRMINGHAM
TUSCALOOSA
SUMPTER MILLS
MOBILE AND OHIO R.R.
NORTH AND SOUTH R.R.
ALABAMA R.R.
ALABAMA AND CHATTANOOGA R.R.
SELMA, MARION AND MEMPHIS R.R.
ALABAMA CENTRAL R.R.
Tombigbee River
Black Warrior River
Little Warrior River
Sipsey Fork
Mulberry Fork
Sipsey River
Buttahatchee River
Luxapallila Creek
Okatibbeha Cr.
Bull Mountain Cr.
Mackey's Cr.
Bear Creek
Sucarnoochee River
Chickasaw River
Bassett's Cr.
Alabama River
Mobile River
HOSS ENGRAVING CO. N.Y.

THE RIVERS OF THE GULF OF MEXICO IN LOUISIANA AND MISSISSIPPI, AND THE TOMBIGBEE IN ALABAMA.

GENERAL DISCUSSION.

From the Sabine, which separates Louisiana from Texas, to the Alabama river, there are only six rivers of much importance, exclusive of the Mississippi and its numerous bayous.

These are the Calcasieu river, draining 3,410 square miles; the drainage system of 1,830 square miles, represented chiefly by the bayou Nezpigue; and east of the Mississippi, the Amite river, draining 1,880 square miles; the Pearl river, draining 8,670 square miles; the Pascagoula, draining 8,350 square miles; and the Tombigbee, which unites with the Alabama to form Mobile river and drains an area of 21,917 square miles.

Distribution of the power.—The line of division between the delta of the Mississippi and the high land crosses the Sabine river at Orange, passes east, about 30 miles distant from the Gulf, to bayou Têche, runs along the west side of the bayou to the Red river, which it crosses at Alexandria, and so passes up the Mississippi. Its course down the east bank of the Mississippi and then east a few miles north of lake Ponchartrain has been already described.

In the Delta the land is low and swampy, and vegetation almost tropical in its luxuriance. The highlands consist largely of "piney-woods lands", where the soil is clay, sand, and gravel.

The rivers, as they flow from the highlands, have a rather rapid descent over gravelly and sandy beds in their upper parts, gradually assuming a more sullen appearance as they increase in size; the beds are more obstructed with snags and fallen trees, the shoals are largely due to sunken logs causing gravel deposits, the heavily-wooded bottoms, which are overflowed in high water, increase in width, and finally they wind through the swamps of the Delta, where even the small tide of the gulf of Mexico extends far up their courses.

As a means of navigation from the pine and live-oak forests of southern Mississippi and Louisiana, and the fertile plantations, these rivers and bayous are of great value, and the late Major C. W. Howell, U. S. engineers, stationed at New Orleans, was engaged in the work of improving them for that purpose. As a means for furnishing power, so much cannot be said, for the smaller of these streams at any rate.

Of water-power there is only 73 horse-power used in the Gulf drainage of Louisiana, under heads of from 5 to 7 feet, and 47 horse-power of this is in or near the Amite basin. This is not because small available water-powers do not exist there. In the "piney-woods lands", the same as in the "hill country" of Mississippi, just described, the river valleys have a rapid descent, and undoubtedly there are available powers on the small streams of the highlands, where there are no extensive bottom lands to deal with, and heavy floods would not destroy all head of water. The reason for no use of water-power probably is that for lumbering, etc., steam-power is very cheap, and far more serviceable than any water-power that could be obtained.

With the rivers which rise far up in the hill country of Mississippi the case is somewhat different, and even the smaller ones, the Amite and Tangipahoa, which rise in Mississippi between the Mississippi and the Pearl river, have some small mills at their sources. Like the Big Black and the streams of the Yazoo basin, the Amite, the Pearl, and the Pascagoula are characterized by small developed powers upon their tributaries and upper waters, but by none upon the large streams.

The census returns credit the Amite basin in Mississippi with 224 horse-power utilized, and of this 88 horse-power is used on the river itself by five flouring-mills and three saw-mills. Within the basin in Louisiana there are three flouring-mills, using a total of 18 horse-power, but no power is taken from the river itself.

From the Tickfaw river, which flows between the Amite and the Tangipahoa, there is 29 horse-power used in Louisiana by three flouring-mills and one saw-mill. There is 74 horse-power in use in the Tangipahoa basin, 38 horse-power by two flouring-mills on the main stream, but there is no power utilized in the basin in Louisiana.

In the upper part of its course in Louisiana the Amite averages 100 feet wide, with a least depth of 1 foot, and an average low-water velocity of 1.4 foot per second. The Tangipahoa runs from 50 to 100 feet in width, with a least depth of 1 foot. The Calcasieu, at Phillips bluff, about 80 miles above its mouth, is about 70 feet wide, with 1 foot depth of water on the shallows.

Having now disposed of the streams west of the Pearl, the basins remaining to be described are those of the Pearl, the Pascagoula, and the Tombigbee. The latter embraces such a variety of country as to necessitate a short separate description.

The first two rivers rise in the highland of Mississippi, especially the Pearl, about whose sources is probably to be found as high an elevation as any in the state. They both flow through the great forest of long-leafed pine, and the basin of the Pascagoula lies entirely within it, as marked out upon the forestry map compiled by Mr. C. S. Sargent, special agent of the census. The pine has been cut near the streams, where it can be easily rafted down to the Gulf, but back from them are vast bodies of the finest timber.

THE PEARL RIVER.

The name of this river was derived from the purity of its waters when nature was allowed her course; since navigation became important, "cut-offs" have been made, the regimen of the river has been disturbed, and it is now a muddy stream, with a rapid current in high water, eroding the banks and causing much damage to property, besides impeding navigation by drift-wood. The United States engineers are endeavoring to improve the state of affairs, and a better idea of the river can scarcely be obtained than from the report made by Mr. H. C. Collins, assistant engineer to Major Howell.

The basin is about 200 miles long, and maintains a width of 40 or 50 miles for nearly the entire distance. The river is navigable to Carthage, 417 miles above its mouth, and the source cannot be much less than 75 miles above Carthage. At Carthage the stream is 170 feet wide, and rises 18 feet above low water, filling the valley. From there down to Jackson, 102 miles below, it has a current of from 1 to 1½ mile per hour, with a 7-foot rise. At Jackson there are bluffs which so restrict the flow that in the extraordinary high water of 1874 the river rose 57 feet above extreme low water; at many places below it rose nearly as high.

Distribution of the power.—As can be readily understood, there are no really available water-powers on the main river, except far up toward the headwaters. By cutting across the numerous bends falls could be obtained, and one of 20 feet is claimed for a bend of 15 miles at Jackson; but such powers as these, if they were not rendered entirely valueless by the floods and back-water, would interfere with the flow of the river for navigation. There is not a mill on the main river using water-power, but on the tributaries there are several, making the total utilized power of the basin 699 horse-power.

The sources are in the pine ridges which form the water-shed between the Pearl and the Tombigbee, and hence the head-streams are very steady and are valuable for small powers. The greater part of the utilized power is on the small creeks; the larger tributaries have few mills, although there are available sites on some of them. The Yokahockony, Tuscalameta, Strong river, and Bogue Chitto are the principal tributaries. According to the census returns the Yokahockony has two flouring-mills, using 30 horse-power, and also two saw-mills, using the same amount, which are, however, only attachments to the flouring-mills. There are several available powers upon the river, one near Kosciusko, with a head of about 10 feet.

The Tuscalameta has no utilized power, and although a rapid stream, has very unstable banks and is unsuitable for power.

The Strong river has two saw-mills, using 36 horse-power. The Bogue Chitto has two flouring-mills, using 18 horse-power.

The distribution in horse-power of the utilized power of the basin according to counties is thus: Choctaw, 30; Neshoba, 185; Copiah, 28; Attala, 32; Rankin, 22; Lincoln, 22; Leake, 144; Simpson, 116; Lawrence, 120.

THE PASCAGOULA BASIN.

This embraces the region between the Pearl and the Tombigbee. The basin is 8,350 square miles in extent. The mouth of the Pascagoula is only 40 miles in a straight line from its head, where it is formed by the union of the Leaf river from the west and the Chickasawhay from the east. The first drains 3,585 square miles, and the second, 2,985 square miles. The Chickasawhay extends far north to the center of the state, and divides near the sources into the Chunky and Oktibbeha creeks. Sixty-two square miles of the basin of the Chickasawhay are situated across the state line in Alabama.

Distribution of the power.—Little is to be said for the water-power of the Pascagoula basin, beyond a repetition of the preceding remarks on the hill-country streams. The main rivers are subject to rapid fluctuations in volume, and overflow their bottom lands, so that practically no water-power is available upon them, except at the headwaters. The Chickasawhay has been navigated by a small boat clear to its head, where the Chunky and Oktibbeha unite. The side streams, especially the larger ones, descend from the high pine lands with rapid fall, and furnish many fine powers, very little developed.

On the Leaf river there is one saw-mill, using 6 horse-power. Tallahala creek, one of its chief tributaries, has one flouring-mill, using 10 horse-power.

The Bogue Homo has one flouring-mill, with 6 horse-power, but Okatoma creek, the remaining large branch, has no mill upon it.

The Chickasawhay river has no utilized power. Its largest tributary, Buckatunna creek, has no mills. The Oktibbeha creek has two flouring-mills, using 53 horse-power.

Between Oktibbeha creek and Chunky creek, at their junction, is one of the largest available heads of water in the state. A small stream flows into the Chickasawhay at that place, and by diverting it over a rock declivity into the Chunky a fall of 70 feet is made available. About a quarter of the power is used by three overshot wheels of 16 feet diameter, ranged one below the other. This power is very poorly developed.

The total power used in the Pascagoula basin is 878 horse-power, thus distributed by counties: Newton, 83; Jasper, 54; Jones, 28; Lauderdale, 310; Clark, 65; Wayne, 67; Smith, 141; Covington, 83; Perry, 47.

THE TOMBIGBEE RIVER.

System of drainage.—Of the 21,917 square miles drained by the Tombigbee about one-third lies in Mississippi and the remainder in Alabama.

The basin starts from a point at the head of Mobile river, where the Tombigbee unites with the Alabama, and gradually widens, with its axis of symmetry nearly a north-and-south line, until at its upper part it reaches a width of 160 miles, extending more than two-thirds of the distance across the state of Alabama. The axis is about 230 miles long, and the head of the basin is determined by the line of water-shed of the Tennessee, the great tributary of the Ohio.

The name Tombigbee is stated to be a corruption of the Indian name Etomba-Igaby, or Box-Maker's creek, given by them to a small tributary, because an old coffin- or cabinet-maker lived on its banks. The river is locally called the "Bigby".

At a distance of 194 miles from the junction with the Alabama it is formed by the union of the "Little Bigby", from the west, and the Black Warrior, from the east. The former drains 9,189 and the latter 6,500 square miles, so the Little Tombigbee is properly the continuation of the main river. These two large forks flow comparatively near the west and east lines of water-shed, respectively, and the crest-line between them does not vary greatly from a straight line passing a little east of north to the Tennessee watershed.

The Little Tombigbee crosses the line between Mississippi and Alabama about 140 miles above its junction with the Black Warrior. It is formed by a number of small creeks in northeastern Mississippi, of which Brown's and Macky's creeks are the chief. The distance from the mouth to Cotton Gin Port is 236 miles, and the junction of Brown's and Macky's creeks may be safely estimated at 50 miles farther up-stream.

The Black Warrior is formed 261 miles above its mouth by the junction of the Sipsey and Mulberry forks, draining, respectively, 1,067 and 582 square miles of territory, so that the river starts off with a tributary area of 1,649 square miles.

The main river, below the union of the Little Tombigbee and the Black Warrior, drains 6,228 square miles, and its chief tributary is the Sacomochee river, on the west. The principal western tributaries of the Little Tombigbee are the Okanoxubee, Oktibbeha creek, and Old Town creek; and those on the east are the Sipsey river, Looxapallila creek, and the Buttahatchee river. The chief branches of the Black Warrior are the Sipsey and Mulberry forks and the Little Warrior, entering from the left.

The following table gives the drainage area of the main stream at various points, considering the Little Tombigbee as its continuation:

Drainage areas of the Tombigbee river.

Station.	Drainage area above station.	Station.	Drainage area above station.
	Square miles.		*Square miles.*
Junction of Brown's and Macky's creeks	312	Below Okanoxubee river	8,718
Below Old Town creek	1,970	Above Black Warrior river	9,189
Below Buttahatchee river	3,288	Below Black Warrior river	15,689
Below Oktibbeha creek	4,526	Below Sacomochee river	18,212
Below Looxapallila creek	5,377	At the head of Mobile river	21,917
Below Sipsey river	7,229		

Drainage areas of tributaries of the Tombigbee river.

River.	Drainage area.	River.	Drainage area.
	Square miles.		*Square miles.*
Old Town creek	688	Sipsey river	763
Buttahatchee	887	Okanoxubee river	1,408
Oktibbeha creek	1,143	Black Warrior river	6,500
Looxapallila creek	818	Sacomochee river	2,441

The Black Warrior has been already stated to drain 1,649 square miles at the junction of the two forks. Below the mouth of the Little Warrior it drains 3,691 square miles, and 4,941 square miles at the town of Tuscaloosa. The Sipsey fork drains 1,067 square miles, the Mulberry fork 582 square miles, and one large tributary, the Little Warrior river, drains 1,218 square miles.

General description of the country.—The country drained by the Tombigbee is nowhere mountainous, strictly speaking, but is undulating or hilly, and owes its topography chiefly to erosion by its water-courses. This is true of all but the eastern extension of the basin, where the Black Warrior rises among the extreme spurs of the great Appalachian system of upheaval as they subside into the undisturbed strata of southern and western Alabama.

The higher elevations of the line of water-shed are probably not over 800 or 1,000 feet above sea-level, and the general level of the upper part of the basin is probably 600 or 800 feet above the sea.

The southern and western parts of the basin are very similar in their general characteristics to the greater part of the state of Mississippi; a rather sandy, gravelly soil—the modified drift brought down by the ancient floods from the north—in some places fertile and in others characterized by "blackjack ridges", alluvial bottoms along the larger water-courses, and heavy bodies of timber; nor must the extensive tract of northern pine in the lower part of the basin be overlooked.

The eastern extension, occupied by the Black Warrior and its tributaries, has a different nature. Above Tuscaloosa the river flows through what is known as the Warrior coal-basin. The country, on the north side of the river more especially, is very rough and rocky, poorly covered with drift, and this with hard wood and stunted pine, and is mainly unfit for cultivation. There are some small fertile bottom-lands along the streams, but these are liable to overflow. The land about the southern tributaries of the Warrior is somewhat better than that northward.

The wealth of this region lies in its valuable beds of bituminous coal, hardly disturbed as yet. A few coal companies have been formed, and two railroads—the Alabama and Chattanooga, and the South and North Alabama—intersect the coal-fields, but the development of the "Warrior basin" is still in its infancy. And this important feature is the existence of valuable iron ores, almost touching the beds of coal. At Birmingham, where the two railroads cross, a mountain on one side of the valley is formed of iron ore, and on the opposite side is the coal for reducing it.

The United States government has had surveys made with a view of extending the navigation of the Black Warrior above Tuscaloosa to the forks by means of dams and locks.

Distribution of available power.—The basin of the Tombigbee presents sharp contrasts; the semi-tropical bottom-lands, with their heavy foliage and sullen rivers, and the sterile, rocky ridges and rapid streams; the exhausted farms of northeastern Mississippi, now covered with small pine, but once rich plantations, and the wild, undeveloped region of Alabama, with scarcely a pioneer hut within it.

The natural navigation is continuous from Mobile, at the level of the Gulf, for about 270 miles, to Fulton, almost at the head of the Little Tombigbee, where small boats go for the cotton trade, and for 169 miles to Tuscaloosa, on the Black Warrior, where the river leaves the coal-basin.

Immediately above Tuscaloosa the slope of the Black Warrior increases, rapids characterize the stream, and it becomes unnavigable. The United States engineers stationed at Mobile, of whom Major Damrell is chief, find it a very different problem in dealing with the upper Warrior from training the lower part of the river and the Tombigbee. On the one the work consists in removing bars, snags, and leaning trees; on the other it will be, if ever undertaken, the building of locks and dams to overcome the rise in the bed.

The available water-power outside of the Warrior coal-basin is on the tributary rivers and creeks. As throughout the state of Mississippi, the large streams flow with a comparatively gentle current, with a low bank on one side or on each side, broad bottoms, overflowed in high water, and loose bed and banks. The side streams largely rise among the sand hills, which store the abundant rains of this parallel and feed the water-courses with a steady supply. From these hills they flow with a rapid current to the main rivers.

The nature of the powers is not essentially different from that of those streams in Mississippi already described, and, indeed, they are many of them only separated by a slight change in level of the same ridge. The most rapid streams, however, and those offering the greatest number of water-powers, are the eastern tributaries of the Little Tombigbee, such as Bull Mountain creek, the Buttahatchee, etc.

Within the Warrior coal-basin the rivers and their tributaries have more the features of mountain streams—not torrents, but rapid—and the Black Warrior itself has rapids and an immense amount of water-power. There are disadvantages belonging to the water-powers of this region not shared to much extent by the other powers of the Tombigbee basin. The water flows rapidly off of much of the rocky, sterile soil, leaving such streams as are fed from it to fall very low in dry weather and filling them to overflowing in rains. Some of the tributaries on the south side of the Black Warrior are fed by springs and are better in this respect; some of them are even fine spring streams. The sources of the main river are sterile, without swamps or many springs, and the river is "flashy".

The great floods to which the Black Warrior is liable practically debar the use of the largest otherwise available powers of the Tombigbee basin. The heavy rains to which the region is subject—from 45 to 55 inches per year—fill the channel of the river from September more or less of the time until April, and sometimes in summer there

are floods washing out the crops along the bottom lands. The high-flood rise is from 15 to 60 feet, according to the locality, and this makes the development of some of the powers impracticable. But the main reason for the undeveloped condition of the powers of the coal region is the entire absence of any demand for them, and it is difficult to see how a demand shall ever exist, unless water-powers should become so valuable as to attract crude material to them.

There is no production of cotton, wool, or other material to warrant the erection of manufactories, except about the outskirts of the region, and there is scarcely a prospect of any being produced within it; and even if there may be in time much demand for power, the cheap coal will be a powerful competitor of the water-powers. However, without a thorough examination it would be hazardous to say that there are no sites upon the Black Warrior river where, by leading the water out of the way of floods, a large head could always be obtained and buildings safely located at a reasonable expense; and the next half century may see some extensive cotton factories run by the power of the river, and manufacturing at home the cotton which has been carried hitherto to New England.

The same financial advantages regarding their relation to the cotton fields which are set forth by Prof. Swain for the South-Atlantic water-powers will apply to the eastern rivers of Alabama, and among them it is perhaps proper to include the Black Warrior. While upon this subject, it may be stated that outside of the region of large water-powers in the parts of Mississippi and Alabama already discussed, there are many available powers of from 50 to 200 horse-power or more, where small cotton and woolen factories or other industries may be started and very profitably carried on.

Distribution of utilized power.—Before giving, so far as possible, the individual features of the principal streams of the basin, a statement will be made of the utilized power as given in the census returns.

The total utilized water-power is about 2,614 horse-power, 736 in Mississippi and 1,878 in Alabama. In the basin of the Little Tombigbee there is 1,162 horse-power in use, 644 in Mississippi and 518 in Alabama, and 1,161 horse-power is utilized in the basin of the Black Warrior. Two hundred and ninety-one horse-power is used in the basin of the main river below the mouth of the Black Warrior. The power in use is thus distributed by counties:

Counties in Mississippi:	Horse-power.	Counties in Mississippi:	Horse-power.
Prentiss	53	Lowndes	74
Tishomingo	57	Oktibbeha	40
Lee	150	Winston	58
Itawamba	28	Noxubee	105
Chickasaw	11	Kemper	92
Monroe	68		

Counties in Alabama:	Horse-power.	Counties in Alabama:	Horse-power.
Lawrence	20	Walker	195
Marshall	24	Jefferson	256
Etowah	21	Pickens	67
Blount	267	Tuscaloosa	237
Winston	61	Hale	90
Marion	72	Sumter	10
Lamar	334	Choctaw	44
Fayette	25	Clarke	155

There is a total of 190 establishments using water-power in the Tombigbee basin; 154 flouring- and grist-mills, 27 saw-mills, 4 cotton-gins, 2 woolen-mills, 1 cotton factory, and 2 manufactories of leather. Of these establishments, 137 are in Alabama and 53 in Mississippi, as follows:

State.	Flouring- and grist-mills.	Saw-mills.	Cotton-gins.	Woolen-mills.	Cotton factories.	Leather manu-factories.
Alabama	108	23	4	2	.....	.....
Mississippi	46	4	.....	.....	1	2

The powers on the principal streams are compiled from the census returns, as follows:

The Tombigbee and Little Tombigbee have no utilized water-power.

The Buttahatchee river has five flouring- and grist-mills, using 70 horse-power, under heads of from 3 to 20 feet.

Old Town creek and Tibbee creek have no improved powers.

Looxapallila creek has two flouring- and grist-mills, using 22 horse-power, under heads of 7 and 15 feet, and one saw-mill, using 16 horse-power, under a head of 14 feet.

Sipsey river has three mills.

Okanoxubee river has two flouring- and grist-mills, using a total of 40 horse-power, under heads of 6 and 9 feet.

Sacamochee river has no utilized power.

The Black Warrior proper has 62 horse-power, used by three flouring- and grist-mills and one saw-mill below Tuscaloosa. All have a head of 8 feet but one.

The Sipsey fork of the Black Warrior has two flouring- and grist-mills, using a total of 28 horse-power, under heads of 30 and 7 feet.

The Mulberry fork of the Black Warrior has two flouring- and grist-mills, using 50 horse-power, and a saw-mill with 20 horse-power. The heads are 10, 7, and 6 feet.

The Little Warrior has three flouring- and grist-mills, using 50 horse-power total, under heads of from 6 to 12 feet; two saw-mills, using 27 horse-power, under heads of 7 and 10 feet; and one woolen-mill, for which the head is unrecorded, using 8 horse-power.

Considering the main stream to extend from the junction of Brown's and Macky's creeks to the junction with the Alabama, the Tombigbee has not a water-power in use upon it. The banks are low as a usual thing, and the stream has a rather sandy bed, which conditions render it poor for the utilization of power, let alone the floods to which it is subject.

In flush stages small steamers run even to Fulton, in Mississippi, and a flat-bottomed steamboat about 200 feet long makes trips during the late winter and spring to Aberdeen, 470 miles from Mobile. At Fulton the river runs on the west side of a heavily wooded, swampy bottom-land, from 1 to 1½ mile wide, and is itself about 150 feet in width, with a strong, silent current, deep and dark. The west bank is steep and firm, but the east is swampy.

At Columbus, 36 miles above the crossing of the state line, the river is about 300 feet wide, with rim-banks some 10 feet high. These are in some places of clay and in others a fine sand. Beside the river at this place there is some clean white sand, which rivals in purity the remarkable Saint Peter sandstone found in Minnesota and Wisconsin. At the crossing of the Alabama Great Southern railroad, some 45 miles above the mouth of the Black Warrior, the river when seen in a high stage was 400 or 500 feet wide between the natural banks, but had overflowed the low eastern bank and flooded the bottom land, which is timbered. The west bank is a bluff about 30 feet high, consisting chiefly of a light-gray rock, probably limestone.

Sources of the Tombigbee.—The sources of the Tombigbee are, strictly speaking, Brown's and Macky's creeks. These drain together 312 square miles, of which Brown's creek has rather more than half. Brown's creek divides into Big and Little Brown's creeks and Hurricane creek. Brown's creek near its mouth is 25 or 30 feet wide in the shallow places, with a depth at such points of from 1 to 1½ foot, and a rapid current. Macky's creek at Bay Springs, where about half its drainage area is tributary to it, is from 25 to 40 feet wide, from 3 to 5 feet deep, and with a moderate current.

These and the neighboring streams usually have a freshet in the fall, and along through the winter and spring are subject to more or less high water; but they do not have such immense rises as occur on the large rivers, probably on account of the sand ridges, and the swamps, in which a greater proportion of the flood-water is held back than along the main streams.

On these streams are many available powers, and numerous small mills which do local grinding, chiefly of corn, and a few have a saw-mill addition. The census returns show four flouring- and grist-mills on Brown's creek, using 45 horse-power, all under a head of 5 feet, and 57 horse-power used by three flouring- and grist-mills and two saw-mills on a stream entitled Spring creek, which is probably Macky's creek.

Bay Springs, on Macky's creek.—At Bay Springs, on Macky's creek, is probably the finest power in that section, if not in the state. It is the most extensively developed power of the entire region, but is by no means fully improved. The little village of Bay Springs consists of the manufactories, store, and house of Mr. Nelson, the proprietor and operator, and the few dwellings of the workmen.

On the left bank is a cotton factory, and on the east bank is a grist- and saw-mill, with a cotton-gin and one or two other small attachments. A peculiar feature of the place is the appearance of rock, and the buildings are set on solid sandstone. The creek runs through a gorge, with rocky cliffs about 150 feet apart and 30 feet high. These and the solid rock bed make the situation admirable for the dam, which is a framed structure, giving a head of 11 feet to the mills set directly at its stone abutments. The head could be increased to 30 feet, and it is claimed that this would not flood land of any considerable value above. Probably the land could be readily bought for two dollars per acre.

The cotton factory has a 55-inch turbine, and on the other side is a 50-inch wheel, besides three others of from 16 to 27 inches, used at times to drive the small machines mentioned. The wheels are not run at full capacity, and there is abundance of water for all the work now done with the present head. Mr. Nelson claims that with a head of 30 feet there would be 500 horse-power available most of the year, but probably during the dry season it would not be over 150 or 200 horse-power. There is no trouble from back-water, as the flow passes rapidly down the gorge. If the water is ever carried any distance down-stream from the dam it will have to be taken in flumes, or else in races blasted out of the rock. The head of 30 feet would raise the level about to the crest of the gorge. Unless extensive improvements are undertaken it seems preferable to set the wheels at the dam, and to transmit the power by wire-rope or shafting.

One great advantage which makes this power almost unique among those of Mississippi is the extensive exposure of solid rock in the bed and banks, and the excellent building-stone afforded for dam and buildings. The rock is a light grayish sandstone of rather fine grain, which works easily and is considered to be excellent

stone. Where exposed to the weather the angles are sharp, and the cliffs show that it breaks in true bedding planes and in large straight blocks. Iron stain shows in places, but the abutments of the mill dams, built of this stone, have weathered with a rather pleasing tint. Judging from appearances, the stone could be quarried over a large tract, and if near a market would undoubtedly be valuable. The distance from the Mobile and Ohio, and also from the Memphis and Charleston railroad, is about 20 miles, over which branch roads could be easily constructed.

There was once a mill on Macky's creek, several miles below Bay Springs, with 11 feet head of water. One bank there is high, but the other is low and expensive to maintain.

Twenty-Mile creek enters from the west, and although draining about 200 square miles, has low sandy banks and is not adapted to water-power.

Bull Mountain creek is a stream rising in Alabama and draining some 360 square miles. It is described as a good stream, with several fine unimproved water-powers upon it.

Old Town creek runs chiefly through swamps, with low banks, and is not adapted for water-power except perhaps at the sources. At the levee, in the swamp near Tupelo, it is not over 25 or 30 feet wide, but runs with a good current and is claimed to be 30 feet deep at that place. It is a characteristic of these streams that they carry more water than would appear at first sight, owing to their depth.

Buttahatchee river.—The Buttahatchee drains 887 square miles, and is a fine, strong stream, with considerable fall, and several mills already mentioned, besides undeveloped powers. The bed and banks are usually of sandy clay and gravel. The high rises to which the Little Tombigbee is subject back about 6 miles up the Buttahatchee. It is considered rather steadier in flow than the neighboring streams, and it is usual to calculate upon about 50 horse-power with a head of 5 feet, although part of the year there is much more. The eastern tributaries of the Little Tombigbee are considered as a rule more reliable than those from the west, because the latter are to a considerable extent lost by evaporation and filtration in the swamps, which are too large for them, and in the sandy soil. This is somewhat the state of affairs on the east side of the river also. Thus, Lubbub creek, which enters below the Looxapallila and drains about 345 square miles, has more volume in the upper part than near the mouth. It has a few mills upon it obtaining about 30 horse-power under a head of 8 feet.

Oktibbeha creek drains 1,143 square miles, but has no mills upon it, little if any available power, and is almost lost in the bottoms near its mouth. Where the Mobile and Ohio railroad crosses it is difficult to distinguish the creek from the sloughs into which it spreads.

Looxapallila river.—The Looxapallila drains 818 square miles, and has several mills upon it, besides powers that are undeveloped. It enters the Little Tombigbee below Columbus, and near its mouth is 75 or 100 feet wide, with a steady, moderate current and sand and gravel banks.

One of the best mills in this section is the Jamieson mill, 9 miles from Columbus. Two and a half miles up-stream a pile-dam has been built across, turning the water into a race to the mill. A head of 16 feet is available, and 14 feet is used. There is 75 horse-power used by the mill, and the proprietor claims that at least 100 horse-power can be depended upon with the full head of 16 feet. Judging from the size of the river, this estimate seems small. Allowing an average low flow of only 0.3 cubic foot per second per square mile, and this is a low estimate for the region, gives over 400 theoretical horse-power under a head of 16 feet.

The high water is usually from January into April, and sometimes in December. The banks and bed are of sand and gravel, which characterize the stream. Usually there is one high bank and one low one.

According to a line of levels run, the river at the Jamieson mill is 56 feet above low water at its mouth, some 15 miles distant along the channel, and yet the high rises on the Tombigbee back the water up nearly to the floor of the mill. This lasts only a short time, as it is the result of the extreme rise on the main river.

All powers below the Jamieson mill are, of course, practically useless.

Sipsey river.—The Sipsey basin is 763 square miles in extent, and lies wholly in Alabama. It is about 90 miles long, and does not average over 10 miles wide.

The river rises in a rough, broken country, and flows through it between rocky bluffs for 40 or 50 miles. Then for about 95 miles (United States engineers' reports) the banks are steep soil bluffs, from 5 to 15 feet high, and then blue limestone is met, and the river is bounded by rocky bluffs for the remaining 22 miles to its mouth. The total fall in the last 145 miles from the north line of Fayette county is 85 feet. The average width of the stream is from 50 to 80 feet. The river was declared navigable by the legislature in 1837, and a company chartered to navigate it, but the right was reserved to erect dams so that they did not interfere with navigation. One-hundred-ton flatboats can navigate the river for from three to six months of the year. They float directly over the crests of the dams, and carry chiefly coal and cotton.

There are seven mill-dams, in a more or less dilapidated condition, but only three mills are working. These are the Sipsey mills, 9 miles from the mouth, and two mills in Fayette county, on the upper part of the river.

The Sipsey mills have a head of 7 feet, and the best improved power on the river; there is a flouring- and grist-mill, with six runs of stones, a saw-mill, and a cotton-gin. The next power has a flouring- and grist-mill and a cotton-gin, with a head of 4½ or 5 feet. The last power has a grist- and a saw-mill, with a head of 6½ feet, and ranks next to the Sipsey mills in importance.

The rim-banks of the river are usually sandy clay and gravel, and generally this forms the bed, but in some places there is solid rock. Floods take some time in disappearing, and back-water is a disadvantage to powers. The mills are hindered from one month to three months in winter and spring from this cause. As on the other streams of this region, there are freshets in winter and spring, sometimes from November on. The range between low and high water at the Sipsey mills is from 25 to 27 feet. Floods on the Little Tombigbee back 2 miles up the Sipsey. With a head of 8 feet at least 100 horse-power can be depended upon in the lower part of the river.

For the first 15 or 20 miles above the mouth the banks are high, and the river runs rapidly, giving available powers. At the head of back-water from the Little Tombigbee there is an available head of 8 feet. Above that for many miles the stream is more sluggish, and any available power would be under great disadvantage from back-water. Beyond this at the head-waters the river is rapid once more.

Okanoxubee river.—The Okanoxubee river drains 1,408 square miles, lying mainly in Mississippi. It is a rather sluggish stream, and has only two flouring- and grist-mills, situated on its upper part, and using 15 and 25 horse-power, under heads of 6 and 9 feet, respectively. The sources are among the sandy pine ridges, and give fine powers. The Hashugua cotton-mills, at Fern Springs, have a head of 11 feet and wheel-capacity for 80 horse-power.

Sacamochee river.—The Sacamochee river drains 2,441 square miles, and enters the main Tombigbee below the Black Warrior. It has no improved power, and there is very little, if any, within the basin.

Bassett's creek, in Clarke county, is the only water power stream of special note entering the Tombigbee below the Black Warrior. It drains about 290 square miles. Upon it are three flouring- and grist-mills, using 8, 10, and 8 horse-power, under heads of 10 and 11 feet, respectively, and one saw-mill, using 30 horse-power, under a head of 12 feet, as given in the census returns.

BLACK WARRIOR RIVER.

The name Black Warrior is derived from the Choctaw name Tuscaloosee (*Tusca*, warrior, and *loosee*, black).

The river's drainage basin of 6,500 square miles is divided into 1,067 square miles, drained by the Sipsey fork; 582 square miles, drained by the Mulberry fork; 1,218 square miles, drained by the Little Warrior, called by some the Locust fork; and 3,633 square miles, drained by the smaller tributaries, of which none drain more than about 300 square miles. North river is one of the largest.

Mention has been made of the United States engineers' surveys for the improvement of the river by slack-water, the great rises to which it is subject, the rapid descent in places, and the disadvantages under which the water-powers are placed.

A United States survey made by Professor E. A. Smith, state geologist, and then assistant United States engineer, showed the total fall in the 92 miles from the junction of the Sipsey and Mulberry forks to Tuscaloosa to be 163.84 feet. There is 65 feet of fall in the first 25 miles above Tuscaloosa, 107 feet in the first 31 miles, and 129.5 feet to the head of Fork shoals, 48 miles above Tuscaloosa In the remaining 44 miles the fall is only about 34 feet. The descent is largely concentrated in shoals, where there will be 5 or 10 feet fall within from 1 mile to 2 miles. In the first 2½ miles above Tuscaloosa there is a fall of 24.6 feet. The largest concentration on the river is at Squaw shoals, where there is 41.5 feet of fall in less than 5 miles. Below Tuscaloosa the river leaves the coal-basin, and the slope is much less, there being only 30.1 feet of fall to the mouth, 169 miles below.

The width of the river runs from 400 to 700 feet above Tuscaloosa, and on some of the shoals spreads out to over 1,000 feet. Below Tuscaloosa it gradually diminishes to an average of about 150 feet near the mouth.

The rise from low to high water is very great at places, but shows a large variation, according to the locality. At Tuscaloosa it is 60 feet (63 feet in the spring of 1881); at the foot of Squaw shoals, 20 feet; and at the head of Squaw shoals, 15 feet. At the foot of Fork shoals, just below the mouth of the Little Warrior, the rise is 15 feet, and above the shoals it is 25 feet. At Payne's mill, some distance below the forks, it is 40 feet, and at the junction of the two forks which form the river it is 50 feet. The extreme rise at Tuscaloosa is due to a sudden decrease of the slope and the contraction of the width of the channel from 400 to 300 feet (low water).

The extreme low-water flow at Tuscaloosa has been measured at 455 cubic feet per second, giving a flow of 0.092 cubic foot per second per square mile (indicative of its unsteady character), and 516 theoretical horse-power under a head of 10 feet. The bed of the river is largely sandstone of the coal measures, and there are many sites affording good banks and bed for improvements. The disadvantage to water-power resulting from the extreme rises of the river have been already pointed out, and also the small demand for power. There are two cotton factories at Tuscaloosa, and a spinning-mill proposed, and it is probable that the large power there would be used if it were at all practicable. Above Tuscaloosa there can scarcely be any demand for a large water-power yet.

Utilized power of the Black Warrior basin.—The total power utilized in the Black Warrior basin is 1,161 horse-power, as stated in the census returns, used by fifty-seven flouring-mills, sixteen saw-mills, and four cotton-gins.

In the basin of the Sipsey fork there are eight flouring- and grist-mills, using 81 horse-power; two flouring- and grist-mills, and one saw-mill in the basin of the Mulberry fork, using 72 horse-power; and the basin of the Little Warrior has a total of 506 horse-power, used by twenty-three flouring- and grist-mills, eleven saw-mills, four cotton-gins, and one woolen-mill. The basin of the Black Warrior, exclusive of these, has 512 horse-power in use by twenty-four flouring- and grist-mills, four saw-mills, and one woolen-mill.

The main river is credited with 62 horse-power, used by one saw-mill and three flouring- and grist-mills, in Hale county, below Tuscaloosa. There are two grist-mills on the river above Tuscaloosa, which consist of scarcely more than a pair of burrs with a shed over them.

The Sipsey fork has two flouring- and grist-mills, using 20 and 8 horse-power, under heads of 30 and 7 feet, respectively, and the Mulberry has two, using 15 and 35 horse-power, under heads of 10 and 7 feet, in addition to a saw-mill, using 20 horse-power, under a head of 6 feet.

The Little Warrior river furnishes three flouring- and grist-mills with 24, 18, and 8 horse-power, under heads of 12, 8, and 6 feet, respectively; two saw-mills with 12 and 15 horse-power, under heads of 7 and 10 feet; and one woolen-mill, near the source, with 8 horse-power.

About the most improved of the smaller tributaries of the Black Warrior is Black Water creek, which enters from the north, below the forks. It drains about 290 square miles, and has four flouring- and grist-mills, using a total of 95 horse-power, under 8, 10, and 15 feet head of water.

Mr. Dwight Porter's report treats of the Alabama, Coosa, and other rivers lying east of the Tombigbee.

INDEX TO REPORT OF THE MISSISSIPPI RIVER, ETC.

A.

Page.

Apple river 80
Artesian well water-power at Prairie du Chien, Wisconsin 100, 101
Average flow 29–36

B.

Baraboo river 93, 94
Basin of the Mississippi 2, 3
  Discussion of 1, 2
Basins, general description of the rivers and their 94–96
Big Black, Big Pierre, and Homochitto rivers 142
Big Cottonwood river 74
Big Muddy river 139
Big Pierre, Big Black, and Homochitto rivers, the 142
Black river 86, 87
Black River falls 87
Black Warrior river 150, 151
Blue Earth river 74, 75

C.

Canal and on the Des Plaines and the main rivers, powers on the 121–130
Cannon river 96, 97
Cannon, Zumbro, Root, Upper Iowa, and Turkey rivers 94
Character of the power 46–49
Chippewa Falls—the only utilized power 84, 85
Chippewa river 72, 81–83
  Tributaries of the 85
Clam river 80
Comparison of the Mississippi with other rivers 1, 2
Constructions, dams, and other engineering 54, 55
Course of the Mississippi, general description of the 6, 7
Crooked creek and Macoupin creek 138
Crow river 63, 64
Crow Wing and the Minnesota, tributaries between the 62, 63
Crow Wing river 62
Crow Wing, rivers above the 61, 62

D.

Dams and other engineering constructions 54, 55
Description of the—
  Locality, general 43
  Water-powers 105–117
  Water-power sites of the Mississippi river 37
Des Moines rapids 60, 61
Des Plaines and the main rivers, powers on the canal and on the 121–129
Detailed description of the improvements 49
Discharge, power, rainfall, drainage area, etc., of the tributaries of the Mississippi river 20
Discovery and early explorations of the Mississippi river 4–6
Discussion and explanation of the tables of flow, rainfall, etc 21–23
Discussion of the tributaries of the Mississippi 61
Drainage area, elevation, rainfall, flow, power, etc.—
  For various points on the Mississippi river 16–19
  Of the tributaries of the Mississippi river 20

E.

Early explorations and discovery of the Mississippi river 4–6
Eastern tributaries of the Mississippi—
  Between the Ohio and the Yazoo 139, 140
  From the Illinois to the Ohio 138
  From the Yazoo to the mouth 140, 141

Page.

East side of the Mississippi from the Rock to the Illinois river, tributaries of the 118, 119
Eau Claire river 85, 86
Elevation, drainage area, rainfall, flow, power, etc., for various points on the Mississippi river 16–19
Elk river 63
Engineering constructions, dams and other 54, 55
Explanation and discussion of the tables of flow, rainfall, etc 21–23

F.

Falls, Pokegama 37, 38
Farnham and Lovejoy power (*b*) 52
Flow, average 29–36
Flow of the streams 25, 26
Flow, power, elevation, drainage area, rainfall, etc.—
  Explanation and discussion of the tables of 21–23
  For various points on the Mississippi river 16–19
Fox river 134–137

G.

General description of the—
  Course of the Mississippi 6, 7
  Locality near Saint Anthony falls 43
  Minnesota river 65–68
  Rivers and their basins 94–96
General discussion of the—
  Mississippi basin 1–2
  Rivers of the gulf of Mexico in Louisiana and Mississippi and the Tombigbee in Alabama 143, 144
Geological history of the falls of Saint Anthony 44–46
Geology of the Mississippi basin 10–12
Grand Rapids 38
Grand Rapids to Little Falls, the river from 38
Gulf of Mexico in Louisiana and Mississippi and the Tombigbee in Alabama, the rivers of the 143

H.

History of the falls and of their improvement 43, 44
Homochitto, Big Black, and Big Pierre rivers, the 142
Hydrology of the Mississippi basin 13–15

I.

Illinois river 119–121
Illinois to the Ohio, eastern tributaries of the Mississippi from the 138
Illinois, tributaries of the 130
Improvements, detailed description of the 49
Improvements of the Saint Anthony Falls Water-Power Company, etc 49–52

K.

Kankakee river 130–134
Kaskaskia river 138, 139
Kettle river 80
Kickapoo river 94

L.

Lac Qui Parle river 71
Lemonweir river 93
Little Falls 39, 40
  The river from Grand Rapids to 38
  To Sauk Rapids, the river from 40
Louisiana and Mississippi and the Tombigbee in Alabama, the rivers of the gulf of Mexico in 143
Lower Mississippi 7, 8

M.

Page.

Mackinaw river 137
Macoupin creek and Crooked creek 138
Main river 77–79
Menomonee river 86
Mill Company, Minneapolis 52–54
Minneapolis Mill Company 52–54
Minnesota river 64, 65
General description of the 65–68
Tributaries between the Crow Wing and the 62, 63
Tributaries of the 71
Water-power sites on the 68–71
Mississippi and the Tombigbee in Alabama, the rivers of the gulf of Mexico in Louisiana and 143
Mississippi basin, general discussion of the 1, 2
Geology of the 10–12
Hydrology of the 13–15
Mississippi river—
Basin of the 2, 3
Compared with others 1, 2
Discussion of the tributaries of the 61
In Wisconsin, tributaries of the 75
Its discovery and early explorations 4–6
Water-power sites 37

N.

Namekagon river 79, 80
Navigation and river improvement 8, 9

O.

Ohio and the Yazoo, eastern tributaries of the Mississippi between the .. 139, 140
Ordinary low flow of the main river above the Minnesota 28–29

P.

Pascagoula basin, the 144, 145
Pearl river, the 144
Pokegama falls 37, 38
Pomme De Terre river 71, 72
Power of flow of the Mississippi at and near Minneapolis, character of the 46–49
Power, drainage area, rainfall, discharge, etc.—
Of the tributaries of the Mississippi river 20
For various points on the Mississippi river 16–19
Power, the Farnham and Lovejoy 52
Powers on the canal and on the Des Plaines and the main rivers 122–130
Powers on the main stream of Black river 87

R.

Rainfall, drainage area, discharge, power, etc.—
Of the tributaries of the Mississippi river 20
Upon the Mississippi basin 23–25
For various points on the Mississippi river 16–19
Explanation and discussion of the tables of 21–23
Rapids, Des Moines 60, 61
Rapids on the main stream, Chippewa river 83, 84
Rapids, Rock Island 56–60
Redwood river 72, 73
Reservoir system of the Mississippi river 9, 10
River below Saint Anthony falls 56
River from Grand Rapids to Little Falls 38
River from Little Falls to Sauk Rapids 40
River from Sauk Rapids to Saint Anthony falls 41
River improvement and navigation of the Mississippi 8, 9
Rivers above the Crow Wing 61, 62
Rivers and their basins, general description of the Cannon, Zumbro, Root, Upper Iowa, and Turkey 94–96
Rivers of the gulf of Mexico in Louisiana and Mississippi and the Tombigbee in Alabama 143
Rock Island rapids 56–60
Rock river 101–105
Tributaries of the 117, 118
Rock to the Illinois river, tributaries of the east side of the Mississippi from the 118, 119
Root river 98

Page

Root, Upper Iowa, Turkey, Cannon, and Zumbro rivers, the 94
Rum river 64

S.

Saint Anthony falls—
At Minneapolis, water-power of 41–43
The river below 56
The river from Sauk Rapids to 41
Water-Power Company, etc., improvements of the 49–52
Saint Croix river 75–77
Tributaries of the 79
Sangamon river 138
Sauk Rapids 40, 41
The river from Little Falls to 40
To Saint Anthony falls, the river from 41
Sauk river 63
Smaller tributaries 81
Snake river 80
Spoon river 137, 138

T.

Table giving the drainage area, rainfall, discharge, power, etc.—
Of the tributaries of the Mississippi river 20
For various points on the Mississippi river 16–19
Tomahawk river 93
Tombigbee in Alabama, the rivers of the gulf of Mexico in Louisiana and Mississippi and the 143
Tombigbee river, the 145–150
Topographical features of the basin of the Mississippi 3, 4
Tributaries between the Crow Wing and the Minnesota 62, 63
Tributaries of the—
Chippewa river 85
East side of the Mississippi from the Rock to the Illinois river 118, 119
Illinois 130
Minnesota 71
Mississippi, discussion of the 61
Mississippi in Wisconsin 75
Rock river 117, 118
Saint Croix river 79
Wisconsin 93
Saint Croix, smaller 81
Tributaries, the Yazoo and its 141, 142
Turkey, Cannon, Zumbro, Root, and Upper Iowa rivers, the 94
Turkey river 99, 100

U.

Upper Iowa river 69
Upper Iowa, Turkey, Cannon, Zumbro, and Root rivers, the 94
Utilized power, Chippewa falls, the only 84, 85

V.

Vermillion river 137

W.

Water-power at Prairie du Chien, Wisconsin, artesian well 100, 101
Water-Power Company, etc., improvements of the Saint Anthony Falls. 49–52
Water-power of Saint Anthony falls at Minneapolis 41–43
Water-power sites of the Mississippi river, description of the 37
Water-power sites on the Minnesota river 68–71
Water-powers of the Mississippi, description of the 105–117
Whetstone river 71
Wisconsin river 87–93
Wisconsin, tributaries of the 93
Wisconsin, tributaries of the Mississippi in 75

Y.

Yazoo and its tributaries 141, 142
Yazoo to the mouth, eastern tributaries of the Mississippi from the 140, 141
Yellow Medicine river 72
Yellow river 80–93

Z.

Zumbro river 97–98
Zumbro, Root, Upper Iowa, Cannon, and Turkey rivers, the 94

REPORT ON THE WATER-POWER

OF THE

REGION TRIBUTARY TO THE MISSISSIPPI RIVER

ON THE WEST, BELOW DUBUQUE, IOWA,

BY

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TABLE OF CONTENTS.

	Page.
LETTER OF TRANSMITTAL	vii

I.—THE MISSOURI RIVER BASIN.

GENERAL CHARACTERISTICS	1
POSITION AND EXTENT	1
THE MOUNTAINOUS SECTION	1,2
THE PRAIRIE SECTION	2
GEOLOGY	2,3
GENERAL FEATURES OF THE PRAIRIE STREAMS	3,4
CLIMATE	5–7
Temperature	5
Winds	5
Humidity	5
Rainfall	5,6
Snow	6
Effects of rainfall, etc., on the streams	6,7
Droughts	7
Increasing rainfall	7

II.—THE MISSOURI RIVER.

MISSOURI RIVER	7–14

III.—TRIBUTARIES ON THE EAST SIDE OF THE MISSOURI RIVER, BELOW YANKTON.

DAKOTA RIVER	14–16
VERMILION RIVER	16
BIG SIOUX RIVER	16–20
ROCK RIVER	20
TRIBUTARIES OF THE MISSOURI RIVER IN WESTERN IOWA	21–27
FLOYD RIVER	22
LITTLE SIOUX RIVER	22–24
SOLDIER RIVER	24
BOYER RIVER	24
MOSQUITO RIVER AND KEG CREEK	25
NISHNABATONA RIVER	25,26
TRIBUTARIES OF THE MISSOURI RIVER IN NORTHERN MISSOURI	28–34
BIG TARKIO RIVER	28
NODAWAY RIVER	28,29
PLATTE RIVER OF MISSOURI	29,30
GRAND RIVER	31
CHARITON RIVER	32

IV.—TRIBUTARIES ON THE WEST SIDE OF THE MISSOURI RIVER, BELOW FORT RANDALL.

NIOBRARA RIVER	35–37
PLATTE RIVER	37–40
TRIBUTARIES OF THE PLATTE RIVER	40–47
ELKHORN RIVER	41,42
SHELL CREEK	42
LOUP RIVER	42
Tributaries of the Loup river	42,43

Page.

TRIBUTARIES OF THE PLATTE RIVER—Continued.
North Platte river 43, 44
South Platte river 45–47
Tributaries of the South Platte river 47–52
Cache la Poudre river 48, 49
Big Thompson creek 49
Boulder creek 49, 50
Clear creek 50–52
LITTLE NEMAHA RIVER 54, 55
NEMAHA RIVER 55, 56
KANSAS RIVER 56–59
TRIBUTARIES OF THE KANSAS RIVER 59–77
Big Blue river 60–63
Tributaries of the Big Blue river 63–65
Little Blue river 63, 64
Other tributaries 64, 65
Republican river 65–69
Tributaries of the Republican river 69, 70
Smoky Hill river 70–72
Tributaries of the Smoky Hill river 72–75
Solomon river 72–74
Saline river 74, 75
LA MINE RIVER 77
MOREAU CREEK 78
OSAGE RIVER 78–81
GASCONADE RIVER 81–83

V.—THE EASTERN IOWA SLOPE.

EASTERN IOWA SLOPE 84–87

VI.—RIVERS OF THE EASTERN IOWA SLOPE.

MAQUOKETA RIVER 87, 88
WAPSIPINICON RIVER 88, 89
IOWA RIVER 89–92
CEDAR RIVER 93–96
Shell Rock river 96
SKUNK RIVER 97, 98
DES MOINES RIVER AND TRIBUTARIES 98–106
Raccoon river 105, 106
Boone river 106
East Fork of the Des Moines river 106

VII.—THE EASTERN MISSOURI SLOPE.

MERAMEC RIVER 110, 111
SAINT FRANCIS RIVER 111–113

VIII.—THE ARKANSAS RIVER BASIN.

ARKANSAS RIVER BASIN 114–117
Character of the surface 114, 115
Climate 115
General features of the streams 116, 117

IX.—THE ARKANSAS RIVER.

ARKANSAS RIVER 117–122
WHITE RIVER AND TRIBUTARIES 123–128
Black river 125, 126
CANADIAN RIVER 128
NEOSHO RIVER 128–131
VERDIGRIS RIVER 131, 132
SUNDRY TRIBUTARIES OF THE ARKANSAS RIVER 132

X.—THE RED RIVER BASIN.

RED RIVER 133–136
TRIBUTARIES OF THE RED RIVER 136–141

LIST OF ILLUSTRATIONS.

	Page.
Improved power at Sioux Falls	18
Sketch showing cross-section of brush dam at Luverne	20
Sketch showing relation of Missouri River valley in western Iowa to adjoining deposits	21
Lakes near headwaters of Little Sioux river	22
Cross-section of Platte river (of Missouri)	29
Sketch showing cut-off of Platte river, near Platte City	30
Profile across head-waters of Niobrara river	36
Map illustrating drainage from the Platte river	39
Profile of Saint Joseph and Western railroad from Little Blue river to Kearney Junction, on Platte river	40
View near Buffalo, on the Denver, South Park and Pacific railroad	45
View of South Boulder cañon	50
View of Rocky Point, Clear Creek cañon	51
Water-privilege at Clay Center	67
Dam at Bentonsport	103
Water-privilege at Hutchinson	121

LETTER OF TRANSMITTAL.

BOSTON, MASS., *July* 9, 1883.

Professor W. P. TROWBRIDGE,
Columbia College, New York City.

SIR: I have the honor to submit a report upon the water-power of the region tributary to the Mississippi river on the west, below Dubuque. The country thus embraced is of vast extent, and is traversed by numerous long and rapid streams; but, owing to certain features of surface and climate, these streams do not in general offer large available water-powers. The great area which they collectively drain has within recent years been encroached upon by settlement and improved by cultivation at a most wonderful rate; but, as is natural in the earlier stages of development, manufacturing industries have not yet been largely introduced, and the demand for power is still limited. Nevertheless, where it has arisen, as in the case of flouring-mills, almost the sole users of water-power beyond the Mississippi, the streams have very generally been put to service, and at scattered points, such as Cedar Rapids, Sioux Falls, Lawrence, Arkansas City, and others, the development of powers of considerable relative importance has been undertaken.

The examinations upon which this report is based were carried on under your direction during the winter of 1880–'81 and a part of the following spring. Various difficulties were encountered, arising from the rigor of an unusually severe winter, the lack of convenient railroad communications, and the paucity of recorded data such as might be found in a section of older settlement; but sufficient information was perhaps gained to give a fair idea of the characteristic features of the principal streams and their capabilities for supplying power. The same system of estimates elsewhere followed in my reports, and explained in detail in connection with the report upon the region tributary to Long Island sound, has here been continued.

Very respectfully,

DWIGHT PORTER,
Special Agent.

REGION TRIBUTARY TO THE MISSISSIPPI RIVER ON THE WEST, BELOW DUBUQUE.

I.—THE MISSOURI RIVER BASIN.

GENERAL CHARACTERISTICS.

1.—Position and extent.

The area included within the water-shed lines of the Missouri river comprises a great tract of country lying, in the main, northwest of the center of the United States. It stretches from the more immediate basin of the Mississippi, on the east, westward to the main ridge of the Rocky mountains; on the south is the Arkansas river, while to the north it extends into the British Possessions, and is limited by the basins of the Saskatchewan and Assiniboine rivers. It lies approximately between the parallels of 37° and 50° north and the meridians of 90° and 114° west, and measures about 527,000 square miles, distributed as follows:

	Square miles.
British Possessions	15,000
Montana	121,800
Wyoming	71,800
Dakota	115,500
Minnesota	1,700
Colorado	29,600
Nebraska	77,000
Iowa	17,400
Kansas	40,600
Missouri	36,600
	527,000

In regard to its location, perhaps the most important facts to be noted are that it is on the leeward side of a chain of high mountains and is remote from any large body of water. At the nearest approach its boundaries are, in round numbers, 250 miles from the great lakes, 500 miles from the Gulf of Mexico, 500 miles from the Pacific ocean, and 600 miles from Hudson bay. In consequence of this land-locked position, it follows that a wind from any quarter must be robbed of much of its moisture before it can reach even the confines of the Missouri basin.

2.—The mountainous section.

The region which we are considering may, for convenience, be divided into two parts—the mountainous district and the prairies—the former of which I shall first describe. Entering the United States from British America, the great range of the Rocky mountains passes down with a southeasterly trend, its main ridge forming the divide which separates those streams flowing ultimately into the Atlantic from those which reach the Pacific. On either side of this ridge, or "backbone of the continent", are many minor ranges and spurs, which extend the mountainous section a long distance east and west. In Colorado it lies mainly west of the 105th meridian, but in southwestern Dakota the Black Hills carry its limits nearly two degrees farther east.

The resources of this division of the Missouri basin are almost incomparable. Scattered over nearly its entire extent are deposits of gold, silver, iron, copper, and coal, of unknown magnitude. The mountain slopes are densely covered with pine, spruce, and cedar. As much as one-eighth of Montana territory and nearly one-third of Wyoming are said to be timbered. Neither is this section without agricultural value; scattered among the mountains and situated along the river-courses are many large tracts of prairie land, finely adapted to grazing or cultivation. Of the combined area of Montana and Wyoming 30 per cent. is stated to be mountainous; a total of 45 per cent. is regarded as suited to grazing, and 15 per cent. to cultivation.

The average elevation of Montana above the sea is given as about 3,900 feet, of Wyoming 6,400 feet, and of Colorado 7,000 feet. Above these general levels there rise the mountain peaks, which attain altitudes of 10,000 to 16,000 feet above the sea. On some of these snow is found in considerable amounts, even throughout the summer, while on all it is retained long after it has disappeared from lower levels. It thus serves, to a certain extent, as a reservoir for maintaining the flow of the mountain streams. After the snow has disappeared, however, the steep, rocky slopes of the mountains quickly shed the heavy summer rains, and cause rapid oscillations in the streams.

A general similarity is to be seen in the streams which drain the mountain slopes. They descend rapidly, and in their courses through the mountains have often cut their way down to great depths, forming narrow cañons with almost vertical sides. They present certain advantages, and certain disadvantages, to use for power. Their low-water volumes are, as a rule, too small to furnish powers of magnitude, and their valleys are much of the way too narrow to afford convenient sites for building. In the wildest portions of the cañons the rocks rise up almost vertically from the water's edge to heights of 500 to 2,000 feet.

The mountain valleys do, however, widen out at intervals so as to give sufficient room for building purposes. The beds and the banks of the streams, being of solid rock, offer the best of foundations for dams, and the rapid fall renders it possible to make up somewhat for the lack of volume by increased head. The courses of the streams are the only practicable routes for railroads to follow into the mountains, and so in one or two cases, such as the north fork of the South Platte and Clear creek, we find railroads thus built, but usually the mountain streams are destitute of railroad facilities. They are subject to sudden rises at times, but the larger streams are seldom so affected as to be dangerous to properly located establishments. A few lakes of small size are found among the mountains, and might probably be improved for storage. On issuing from the foot-hills these streams are, in most instances, drawn upon for irrigation, which is of much more importance there than any use for power.

3.—The prairie section.

The second great district to be noted in the Missouri basin comprises the prairies, which stretch eastward from the Rocky mountains like a vast sea. They, of course, present varying features, according to their location, some being much more fertile and better cultivated than others, but the following description by Captain William Ludlow will convey a good idea of the less favorable portions of Dakota:

(*a*) The Dakota prairies have been often described, but their general characteristics may be briefly stated: A rolling, and at times a hilly country, destitute of wood, except small quantities in the eroded valleys of streams, and covered with short grass. The horizon, bounded everywhere by the undulating outlines of the surface, and varied occasionally by some more dominating elevations, which constitute the landmarks of the traveler, and are called buttes. The summer sun shines from a generally cloudless sky, the purity of the air gives its rays great power, and the thermometer frequently rises above 100° in the shade.

Water is scarce, and almost invariably alkaline, even in running streams, from the presence of a salt which forms a component of the clayey soil. The rivers are small streams, of great comparative length, which, from absorption and evaporation, shrink in their downward course, and are frequently dry at their mouths, while flowing freely a hundred or two miles above. The seasons of spring and fall are exceedingly brief. The winter snows are rapidly disposed of in the spring, and rainfalls are unfrequent until cold weather in the fall, which soon again merges into winter. By July 1 the grass is full grown, and in another month has turned dry and yellow, cured to hay upon the ground and readily burned.

The great expanse of the prairies has a gradual slope, imperceptible to the eye, toward the east. Denver, which is but a short distance from the foot-hills of the Rocky mountains, is about 5,300 feet above sea-level; advancing directly to the east from this point, we reach the Missouri river, near Atchison, at an elevation of about 800 feet. In this interval of 520 miles there has been an average descent, slowly decreasing in rate, of approximately 8½ feet per mile for the entire distance. This considerable surface slope has the effect of giving the streams a rapid fall, and also secures a good drainage to the soil.

4.—Geology.

All evidence points to the fact that for long periods in geological history the prairies of the Missouri basin lay at the bottom of an inland sea. In the Tertiary period this sea extended from Texas northward into British America, and stretched from the foot-hills of the Rocky mountains eastward beyond the present Missouri river. On the bed of this sea were laid the Pliocene deposits of the Tertiary.

In the Champlain period this sea appeared contracted in size, and over the Tertiary deposits left its burdens of transported Drift. In still later times, when the inland sea had taken on more the appearance of a chain of great lakes, extending along the course of the present Missouri river, the Drift of this section was in turn buried beneath a deposit of Loess.

The Pliocene deposits of the Tertiary form the surface materials in western Nebraska, and are found in northwestern Kansas, extending thence into Colorado. As stated by Professor Samuel Aughey, they are nearly 2,000 feet thick along the foot-hills of the mountains in Colorado. In that vicinity the material of these deposits is exceedingly coarse, and is largely composed of conglomerates. On the south side of the Republican, in Harlan county, Nebraska, Professor Aughey found it made up largely of lime mingled with siliceous materials, and on the Driftwood, south of the Republican valley, it consisted of loosely-compacted sand and pebbles underlaid by limestones and marls.

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a Report of a Reconnaissance of the Black Hills of Dakota, 1874.

In northwestern Kansas, Professor Mudge remarks that—

The material of the Pliocene deposits consists of sandstones of various shades of gray and brown, occasionally whitened by a small admixture of lime. The lower strata are usually composed of finer sand than the upper, and are looser and more friable in their texture. The overlying beds are of coarser ingredients, consisting of water-worn pebbles of metamorphic rocks.

East of the region just described is found the Drift, overlying the Tertiary, and composed as elsewhere of clays, gravels, sands, and bowlders. In Nebraska it ranges in thickness from a few inches to 75 feet, and in Kansas is about 5 feet thick, occasionally increasing to 20 feet. The smaller pebbles and gravel of the Drift occur in Kansas as far south as latitude 38°. The material of this formation is widely diffused in Nebraska, but is seldom exposed in large areas on the surface, usually being covered by later deposits.

The Loess, or Bluff deposit, is met with overlying the Drift, and forming the surface material over a large portion of the country neighboring to the Missouri river. It is supposed to have been deposited in the beds of the old lakes which, at some time, stretched along the course of the Missouri, then, as now, a very muddy stream. I do not know that the entire boundary of this deposit has been accurately defined. Dr. C. A. White has shown clearly its eastern limit in Iowa, where it extends, at the farthest, 50 or 60 miles from the Missouri. In southwestern Iowa it attains a depth of 150 and even 200 feet.

Professor Mudge states that in Kansas the Loess has a thickness of nearly 125 feet at Wyandotte, on the Missouri river, gradually thinning out to the westward till, 100 miles away, it almost disappears. It is said to prevail over at least three-fourths of Nebraska, ranging in thickness from 5 to 150 feet.

The influence of these geological formations on the value of the streams for water-power is important. The Loess is very permeable to water, so that rains falling upon its surface readily penetrate it. Its composition is almost precisely the same in all localities and at all depths, and water percolating through it will sink steadily until some impervious stratum is encountered in the underlying Drift. It may thus sink much below the beds of the streams, and fail to appreciably increase their volume. Some of the streams flowing over the Loess have cut their way down to the Drift, and receive the benefit of the water arrested by that deposit; most, however, have not succeeded in doing this, and suffer in consequence. The Loess material is fine, black, and siliceous, and the streams running over it are characterized by muddy beds and banks, entirely unsuited to dams of ordinary construction, and rendering necessary, in many cases, structures of brush.

The Drift deposit is well supplied with springs, so necessary to the maintenance of a good low-water volume, and occasionally offers firm gravelly beds for dams. Underneath the surface deposits of Drift and Loess are found sandstones and limestones, many of which are of the finest quality for building purposes. Some of the streams, such as the Blue river of Kansas and Nebraska, have cut their channels, at points, down to these strata; but, in general, the river beds are either muddy or sandy.

The effects which the Loess and Drift deposits would naturally have elsewhere upon the flow of the streams are modified here, from the fact that much of the rain falling upon the surface of the ground is unable to penetrate it at all. It must be remembered that the prairies of which we are now speaking are nowhere level, but everywhere present a rolling surface, which easily sheds water. Although they are covered with grasses, timber is extremely scarce, and west of the 98th or 99th meridian is seldom seen at all. From the report of the Kansas state board of agriculture it appears that only about 5 per cent. of the entire surface of that state is timbered. The ground, thus bare, has been exposed, for ages, perhaps, to scorching suns, dry winds, pelting rains, and a pounding by the hoofs of myriads of wild animals, till it has become almost impervious to water. Under these circumstances, rains which otherwise would gradually sink down through the soil are shed almost immediately into the streams, and render them very unsteady.

A valuable remedy for this evil is in the increased cultivation of the soil, which breaks it up and renders it receptive of water. The benefits thus derived by the streams do not admit of doubt. Professor Aughey, in his *Sketches of the Physical Geography and Geology of Nebraska*, gives the results of his own observations upon the formation of new springs and the increase in volume of small streams. In Kansas I took especial pains to inquire into the same subject, and received everywhere uniform testimony; on the Republican, Solomon, Smoky Hill, and in other parts of the state these phenomena have been observed. New springs have made their appearance, and small streams which fifteen years ago ran dry during a part of the year, now always contain running water, and have extended their low-water courses considerable distances back up their valleys. These effects have been especially marked in the Republican valley. In Cloud county, Kansas, on the divide between the Republican and Solomon rivers, water could not formerly be reached in borings, even at a depth of 100 feet, but it is now readily obtained 25 feet below the surface.

5.—General features of the prairie streams.

The streams which drain the prairies display numerous points in common. So far as regards their capabilities in the way of water-power, they may be said, in brief, to present many unfavorable features, while they at the same time offer some advantages. They do not exhibit abrupt falls, but descend with a uniform slope, frequently amounting, in their upper courses, to several feet per mile. Although the dams do not usually throw the water

back so as to flood beyond the banks, the backwater extends far enough up stream to really give a very considerable storage. Where the streams are able to carry off their flood-waters without overflowing, they admit of a very thorough utilization of their power, since they may be improved with almost equal facility at all points. Again, the level bottom-lands which border them offer the most practicable routes for railroads, and, consequently, we find a great many streams skirted closely by finely-equipped lines.

On the other hand, the beds and banks are, as I have elsewhere said, very unfavorable to the security of dams. Where not muddy they are generally sandy, and are frequently composed of a very treacherous quicksand, as in the Republican and the Platte. The head to be obtained is, in general, no more than the lift of the dam. The bottoms bordering the streams range from 1 to 3 miles in width on the smaller ones, and are sometimes two to three times as wide on the larger rivers. They have nearly a level surface at right angles to the streams, and parallel to them a slope nearly coincident with their own. Now and then a river approaches the bluffs on one side, but quickly winds back to the opposite side of the bottom. It is, therefore, impracticable to gain head by use of a canal, except by gradually raising it above the level of the bottom by diking on either side—a construction which has many disadvantages, and which has seldom been adopted on these streams.

A very great objection to the prairie streams is their variability in volume, and the low stage which they reach in certain seasons, notably in late fall and winter. The larger manufacturing streams of the Atlantic slope seldom show a less rate of discharge than 0.30 to 0.50 cubic foot per second to the square mile of drainage area; while there are probably few of those which we have been considering that do not, at some period of the year, fall below a discharge of 0.05 to 0.10 cubic foot per second to the square mile, and some even entirely dry up, or become a chain of stagnant pools. The Kansas river had a volume at Topeka, in the winter of 1874–'75, corresponding to only 0.035 cubic foot per second to the square mile. During the month of October, 1879, the Missouri river itself, with its drainage area of more than 500,000 square miles, showed an average discharge of only 0.0568 cubic foot per second per square mile. From these very low stages the rivers we are considering rise, usually in early summer or midsummer, to relatively very high points. The wider and more rapidly falling usually succeed in carrying off their flood volumes without overflowing their banks; but the narrower and more sluggish ones, for example those of the western Iowa and northern Missouri slopes, spread out far and wide over the bottoms, sometimes reaching widths of 1 mile to 3 miles.

Measurements of flow made at Saint Charles, (*a*) near the mouth of the Missouri river, during the year 1879, presented a variation in volume from 26,446 to 298,537 cubic feet per second, or a range from 0.0502 to 0.5665 cubic foot per second to the square mile of drainage area. From these observations it was inferred that the ordinary range of flow, from low to high water, would be approximately from 15,000 to 430,000 cubic feet per second, or from 0.028 to 0.816 cubic foot per second to the square mile. At this rate the high-water discharge would be nearly thirty times that at low water, and with many smaller streams the disproportion would doubtless appear a great deal more.

In some sections, where Drift constitutes the surface material, many small lakes, technically known as Drift lakes, are met with. They are to be found in Dakota, and there are a few within the limits of the Missouri basin in Iowa. Some have a direct connection with the streams, while a large proportion of them are apparently isolated. They are all probably of some value in maintaining the flow of neighboring streams, either by surface connection or by underground percolation; and where sufficiently numerous and large, as in the Big Sioux basin, in Dakota, they might be made available for increased storage.

Storage of magnitude in artificial reservoirs, so frequently used in New England, is not, however, generally practicable with prairie streams. There are few natural lakes or ponds, except in the limited sections just noted. The positions of the streams, in the midst of broad and fertile bottoms, often seemingly as level as a floor, and seldom approached simultaneously from both sides by the bluffs, would prevent the formation of extensive reservoirs on their courses, unless at great and unbearable expense. Along the foot-hills of the Rocky mountains there are, undoubtedly, numerous depressions which were at some period in the past occupied by small lakes, and which might, at a reasonable outlay, be made available for storage; in fact, this has been done already in a few cases, not with a view to using the stored water for power, but for irrigation. Even if artificial reservoirs should be constructed on the prairies, a great disadvantage would be encountered in the extreme evaporation. On the northern Atlantic slope from 40 to 60 per cent. of the rainfall may be realized; but for the entire Missouri basin Humphreys and Abbot give the ratio of drainage to rainfall as only 15 per cent. At Milford, in northwestern Iowa, power is used at the outlet of Spirit and Okoboji lakes, and I am informed by Mr. T. S. Seymour, secretary of the water-power company, that only a little more than one-eighth of the annual rainfall is counted on there. Storage reservoirs would, perhaps, benefit the prairie streams relatively as much as they do those of the east; but when it is considered that the average rainfall for the entire Missouri basin is only about 20 inches, against 45 inches, more or less, for the north Atlantic slope, and that, of the rain which does fall, only one-third to one-fourth as much can be realized in the former region as in the latter, it is evident that the absolute gain in volume of the streams would be small compared with that obtained by eastern manufacturers from their rivers.

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a See *Preliminary Report* by Major Charles R. Suter.

6.—Climate.

The healthfulness of the climate of the Missouri basin is famous and unquestioned. There are, doubtless, some low valleys in the state of Missouri where fevers and malaria are prevalent, but the high ground is perfectly healthy, and as we advance westward over the prairies, and especially as we approach the mountains, the air is found to be remarkably dry and bracing. Owing to the remoteness of large bodies of water, extreme changes of temperature are not uncommon, but they are much less noticed than in the moister atmosphere of the East.

Temperature.—The following records of temperature are principally from the Smithsonian tables. A number of places well scattered over the Missouri basin are included, and there are also added records of one point in the Gulf states and one in New England. The maxima and minima temperatures are only approximate, being derived from but three to four years of signal service records:

Mean, maxima, and minima temperatures.

Locality.	Elevation above sea.	Latitude.	Longitude.	Years of record.	Mean.					Average maxima.					Average minima.				
					Spr.	Sum.	Aut.	Wr.	Yr.	Spr.	Sum.	Aut.	Wr.	Yr	Spr.	Sum.	Aut.	Wr.	Yr.
	Feet.	° ′	° ′		° ′	° ′	° ′	° ′	° ′	°	°	°	°	°	°	°	°	°	°
Fort Benton, Montana	2,730	47 50	110 39	1	44 70	71 15	48 72	25 14	47 43	.....	.....	.....	.....	.....	− 9	37	− 9	−28	−28
Fort Steele, Wyoming	6,500	41 45	107 10	2	40 99	66 36	45 88	22 48	43 93	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Bismarck, Dakota	1,650	46 47	100 46	3	38 17	66 76	39 94	7 97	38 21	86	100	85	51	100	−18	36	−12	−31	−31
Fort Sully, Dakota	.....	44 50	100 35	3	42 79	72 71	47 30	20 59	45 85	93	107	97	61	107	4	42	11	−12	−12
Yankton, Dakota	.....	42 54	97 21	4	45 02	71 20	46 18	17 14	44 88	88	107	97	61	107	− 8	42	11	−12	−12
Denver, Colorado	5,250	39 45	105 01	4	48 16	70 89	50 58	28 51	49 53	88	101	91	64	101	7	40	8	−15	−15
North Platte, Nebraska	2,800	41 08	100 46	3	47 07	71 95	48 74	23 50	47 81	89	101	96	66	101	0	37	0	−21	−21
Omaha, Nebraska	1,300	41 15	95 56	4	48 40	74 26	51 10	23 36	49 28	88	98	89	59	98	2	44	4	−15	−15
Fort Hays, Kansas	2,107	38 59	99 20	3	53 05	78 52	54 78	33 05	54 85	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fort Leavenworth, Kansas	896	39 21	94 54	40	53 69	75 24	54 35	29 35	53 16	90	100	93	66	100	9	47	10	− 9	− 9
Rolla, Missouri	950	37 58	91 44	4	52 93	74 29	54 24	33 78	53 81	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Saint Louis, Missouri	481	38 37	90 12	41	55 09	76 12	55 88	32 90	55 00	90	97	90	68	97	13	51	16	− 7	− 7
Montgomery, Alabama	162	32 23	86 18	1	66 72	.....	61 66	49 96	.....	95	101	93	77	101	33	62	33	19	19
New Haven, Connecticut	45	41 18	72 57	86	46 76	69 63	51 28	28 32	49 00	82	91	84	56	91	9	47	16	0	0

Winds.—The prevailing winds during the different seasons are shown by the Signal Service records to be as follows:

Prevailing winds.

Locality.	Years of record.	Spring.	Summer.	Autumn.	Winter.	Year.
Fort Benton, Montana	2	SW.	W.	SW.	SW.	SW.
Bismarck, Dakota	4	NW.	NW.	NW.	NW.	NW.
Fort Sully, Dakota	3	SE.	SE.	NW.	NW.	NW.
Yankton, Dakota	4	NW.	SE.	NW.	NW.	NW.
Denver, Colorado	4	S.	S.	S.	S.	S.
North Platte, Nebraska	4	SE.	SE.	NW.	NW.	NW.
Omaha, Nebraska	4	N.	S.	S.	NW.	S.
Leavenworth, Kansas	4	S.	S.	S.	S.	S.
Montgomery, Alabama	4	SE.	S.	NW.	N.	NW.
New Haven, Connecticut	4	NW.	S.	NW.	NW.	NW.

Humidity.—Regarding the humidity of the atmosphere, I have been able to find but one or two continuous records for particular stations, but from the Monthly Reviews in the Signal Service reports, I judge that the relative humidity for the year averages 0.40 to 0.50 in the upper basins of the Missouri and Platte, and 0.60 to 0.70 in the Lower Missouri valley, against 0.70 to 0.75 for the Gulf and New England states. For the year—July, 1877–June, 1878—the mean relative humidity at North Platte, Nebraska, was 0.616, and at Omaha, 0.696. In tables published by Professor F. H. Snow, of the Kansas State University, it appears that the mean relative humidity at Lawrence ranged, for different years, between 0.64 and 0.726, averaging for nine years, 0.672.

Rainfall.—There are not a great many points in the Missouri basin where records of rainfall have been kept for a long series of years, but its general distribution may be sufficiently well judged from the accompanying table, which embraces a number of localities, widely dispersed, where the most extended observations have been taken. The list is copied from the Smithsonian rain tables:

Rainfall.

Locality.	Elevation above sea.	Latitude.	Longitude.	Years of record.	Spring.	Summer.	Autumn.	Winter.	Year.
	Feet.	° ′	° ′		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Fort Ellis, Montana	4,878	45 40	111 00	3	7.17	3.60	2.38	2.59	15.74
Fort Benton, Montana	2,730	47 50	110 40	7	5.34	4.48	1.65	1.79	13.26
Fort Bridger, Wyoming	6,656	41 20	110 23	13	2.99	2.05	1.68	1.71	8.43
Fort Steele, Wyoming	6,840	41 47	106 57	5	4.57	3.48	3.05	4.28	15.38
Fort Laramie, Wyoming	4,472	42 12	104 31	18	5.35	4.40	2.73	1.97	14.45
Fort Buford, Dakota	1,900	48 01	103 58	8	3.76	4.06	2.01	2.01	11.84
Fort Totten, Dakota	1,480	47 56	99 16	5	5.18	7.51	2.50	1.59	16.78
Fort Sully, Dakota	1,672	44 50	100 35	8	6.52	7.18	1.70	1.14	16.54
Yankton, Dakota	1,275	42 53	97 30	3	7.40	13.03	4.00	2.15	26.58
Denver, Colorado	5,250	39 45	105 00	5	5.02	3.69	3.16	1.90	13.77
North Platte, Nebraska	2,789	41 08	100 46	2	6.14	3.83	2.75	0.57	13.29
Fort Kearney, Nebraska	2,360	40 38	98 57	14	7.81	11.13	4.83	1.45	25.22
Omaha, Nebraska	1,300	41 15	95 56	10	7.68	15.00	7.15	3.01	32.84
Fort Hays, Kansas	2,107	38 59	99 20	7	6.93	6.23	5.77	3.77	22.70
Fort Leavenworth, Kansas	896	39 21	94 54	38	7.92	13.07	7.86	4.53	33.38
Fort Riley, Kansas	1,300	39 03	96 35	21	5.49	10.48	5.92	2.63	24.52
Lawrence, Kansas	850	38 58	95 12	9	8.83	12.59	7.38	4.30	33.10
Rolla, Missouri	950	37 58	91 44	9	11.67	11.13	8.04	6.66	37.50
Saint Louis, Missouri	481	38 37	90 12	40	11.71	13.01	8.58	7.39	40.69
Montgomery, Alabama	162	32 23	86 18	4	17.83	12.42	7.87	18.78	56.90
New Haven, Connecticut	45	41 18	72 57	27	11.24	12.11	11.19	10.90	45.44

SNOW.—I have but few data concerning the amount of snow falling on the Missouri basin. The records of Dr. A. S. Childs, of Plattsmouth, Nebraska, show an average of 23.5 inches per year for the fourteen years 1866–'79. Professor Snow gives the average at Lawrence, Kansas, for the five years 1868–'72, as 21.6 inches. Both these places are adjacent to the lower Missouri river. To the westward, on the plains, the snowfall is much lighter; the fall in the Rocky mountains is heavy, and the snow accumulates to great depths in the ravines.

EFFECTS OF RAINFALL, ETC., ON THE STREAMS.—In summing up the main points of the physical phenomena which have been mentioned, it is to be noticed:

(*a.*) That the range of temperature through the year is great, the mercury rising at most stations as high as 100°, and sinking as low as —10°, while in many localities the variation is still greater. The evaporation produced by the hot sun of summer, shining upon the almost unprotected surface of the prairies, is very large, and in a time of drought quickly brings down the volumes of the streams. Thus it is probable that such streams as the James river, of Dakota, and the Osage, of Missouri, during low stages lose as much by evaporation in their lower sluggish courses as they receive in those portions from their tributaries. Over almost the entire area drained by the Missouri the mean winter temperature is below 32°, so that whatever precipitation there is during that season must be mainly in the form of snow, and so remain upon the surface much of the time without greatly benefiting the streams.

(*b.*) For the upper basin, at least, the prevailing winds of the year, and especially of the winter season, are westerly, ranging from southwest to northwest. The winds blow steadily and quite briskly on the plains, there being comparatively few calm days, and coming dry from the Rocky mountains they assist largely in causing a rapid evaporation.

(*c.*) The relative humidity of the atmosphere is small, except in the lower Missouri valley, sinking frequently to 0.40, and at times to 0.30 or less, at Denver and Cheyenne.

(*d.*) The rainfall is small, and unevenly distributed through the year. For the localities represented in the preceding table the mean annual rainfall varies from 8.4 inches at Fort Bridger, Wyoming, to 40.7 at Saint Louis. It is less than 20 inches at most points west of the ninety-ninth meridian. Even more than the small annual rainfall is to be noticed the great contrast between the amounts falling in summer and winter. For points in Montana and Wyoming the precipitation seems to be greatest in spring and least in autumn; but for the Missouri basin, as a whole, the disproportion is greatest between summer and winter. The ratio which the rainfall of the former season bears to that of the latter is in different localities as follows:

Ratio of summer to winter rainfall.

Locality.	Ratio.	Locality.	Ratio.
Fort Ellis, Montana	1.4	North Platte, Nebraska	6.7
Fort Benton, Montana	2.5	Omaha, Nebraska	5.0
Fort Steele, Wyoming	0.8	Fort Hays, Kansas	1.7
Fort Laramie, Wyoming	2.2	Fort Leavenworth, Kansas	2.9
Fort Buford, Dakota	2.0	Saint Louis, Missouri	1.8
Yankton, Dakota	6.0	Montgomery, Alabama	0.7
Denver, Colorado	1.9	New Haven, Connecticut	1.1

The effect of the small precipitation of winter, combined with the low temperature of that season, is to bring most of the tributaries of the Missouri, excepting some farthest south, to their lowest stage in winter. On the other hand, we find them attaining their greatest volume in early and mid summer, a period when streams on the Atlantic coast are either in a falling stage or have reached the minimum.

DROUGHTS.—Concerning the prevalence and duration of droughts I can give no special information. They appear to be more severe, however, in the Missouri basin than on the Atlantic and Gulf slopes. This is indicated in the table below, where are given for a number of points in the above sections the ratios existing between the mean annual rainfall and the rainfall in an ordinarily dry year—not the dryest of a long term, but such as occurs once in five to eight years.

Ratio of rainfall in an ordinarily dry year to mean annual rainfall.

Locality.	Ratio.	Locality.	Ratio.
Missouri basin.		*Missouri basin*—Continued.	
Fort Benton, Montana	0.55	Saint Louis, Missouri	0.79
Fort Laramie, Wyoming	0.43	*Gulf slope.*	
Fort Buford, Dakota	0.60	Montgomery, Alabama	0.91
Yankton, Dakota	0.76	Atlanta, Georgia	0.94
Denver, Colorado	0.83	*North Atlantic slope.*	
Fort Kearney, Nebraska	0.77	Philadelphia, Pennsylvania	0.89
Omaha, Nebraska	0.65	New York city	0.91
Fort Hays, Kansas	0.70	New Haven, Connecticut	0.87
Fort Leavenworth, Kansas	0.76	Amherst, Massachusetts	0.90
Fort Scott, Kansas	0.71	Boston, Massachusetts	0.88
Fort Riley, Kansas	0.69	Brunswick, Maine	0.81
Lawrence, Kansas	0.92		
Rolla, Missouri	0.89		

INCREASING RAINFALL.—I have elsewhere spoken of the influence which the advancing cultivation of the prairies certainly has in the production of new springs and in maintaining the low-water flow of the streams. The same cause is also regarded by some as producing a better distributed and even increased annual rainfall. The subject is discussed in a very thorough manner by Professor Aughey in his work previously alluded to. The effect of cultivation is certainly very favorable, though there may be a question whether observations have been long enough continued to prove that the annual rainfall has been permanently increased.

II.—THE MISSOURI RIVER.

Although the Missouri river possesses no available water-power in that portion of its course which I visited, or, indeed, for a very long way above, yet it may be of interest, before describing the various tributaries, to give some account of the main stream, briefly setting forth its characteristic features.

The upper waters of this river were first explored in 1806, by Captains Lewis and Clarke, at a time when the highest settlement of whites on the stream was at La Charette creek, 68 miles from the Mississippi. Lewis and Clarke ascended the Missouri in small boats, noting down whatever appeared of interest, reconnoitering the tributaries for short distances above their mouths, and meeting with many strange adventures. They carried their explorations the length of the Missouri, and then continued up the Jefferson fork. On returning, Captain Clarke examined the Gallatin fork and a large part of the Yellowstone. For a succeeding period of nearly fifty years but little was added to the knowledge concerning the upper Missouri valley; but from the year 1853 to the present time numerous expeditions, reconnaissances, and surveys have been made by engineers and other officers of the United States Army, in the upper basin of the Missouri. Regarding the lower river, I think very little has been written in a connected and detailed manner. But within the past few years the efforts made for its improvement at various points, under the direction of Major Charles R. Suter, have led to its thorough and scientific study. A careful survey, to extend from the mouth to Fort Benton, is in progress.

The Missouri river proper is formed in southwestern Montana by the union of three forks, which, upon their discovery by Lewis and Clarke, were named by them Jefferson, Madison, and Gallatin, respectively. With reference to them the journal of Captain Lewis says:

On examining the two streams (Jefferson and Madison) it became difficult to decide which was the larger, or the real Missouri; they are each 90 yards wide, and so perfectly similar in character and appearance that they seem to have been formed in the same mold. We were therefore induced to discontinue the name of Missouri, and give to the southwest branch the name of Jefferson, in honer of the President of the United States, the projector of the enterprise; and called the middle branch Madison, after James Madison, Secretary of State. These two, as well as Gallatin river, run with great velocity, and throw out large bodies of water. Gallatin river is, however, the most rapid of the three, and, though not quite as deep, navigable for a considerable distance. Madison river, though much less rapid than the Gallatin, is somewhat more rapid than the Jefferson; the beds of all of them are formed of smooth pebbles and gravel, and the waters are perfectly transparent.

The Jefferson and Madison forks first come together, and within 2 miles are joined by the Gallatin.

The head of the Missouri, thus formed, lies about in latitude 45° 56′, and longitude 111° 32′. From this point the river takes a slightly northwesterly direction for about 80 miles by general course, and then runs northeast for an equal distance to Fort Benton. From the junction of the three forks at its head, the course of the Missouri lies for nearly a degree of latitude through mountain valleys and deep cañons; from these it finally issues through a gorge in a range of rocks, which Lewis and Clarke called the "gates of the Rocky mountains", and of which they gave this description:

A mile and a half beyond this creek the rocks approach the river on both sides, forming a most sublime and extraordinary spectacle. For 5¾ miles these rocks rise perpendicularly from the water's edge to the height of nearly 1,200 feet. They are composed of a black granite near their base, but from the lighter color above, and from the fragments, we suppose the upper part to be flint, of a yellowish-brown and cream color. Nothing can be imagined more tremendous than the frowning darkness of these rocks, which project over the river and menace us with destruction. The river, 150 yards in width, seems to have forced its channel down this solid mass; but so reluctantly has it given way, that during the whole distance the water is very deep, even at the edges, and for the first 3 miles there is not a spot, except one of a few yards, in which a man could stand between the water and the towering perpendicular of the mountains.

Thirty-five miles above Fort Benton the river pours over the Great falls, and from that point onward is a navigable stream. The following, concerning these falls, is from the report of Lieutenant Grover, United States Army:

There are five principal cascades. The first, about 3 miles below the mouth of the Sun river, falls about 25 feet. The second, nearly 3 miles below the first, is a small crooked cascade of 5 feet 11 inches pitch. Immediately below is the third. Here, between high banks, a ledge, nearly as straight as if formed by art, runs obliquely across the river, over which the water falls 42 feet in one continuous sheet, of 470 yards in width. At the foot of this cascade, so beautiful for its length and regularity, is a small island covered with willow, cottonwood, and wild cherry. Half a mile below this, again, is the fourth—a small, irregular fall of about 12 feet descent. There is a small knot of an island near the middle, and between that and the right bank of the river the ledge of the fall is very crooked, and the water reaches the basin below in two pitches. But between the island and the left bank there is simply a succession of rapids; the stream then hurries on, lashed and churned by numerous rapids, about 5 miles farther, where it precipitates itself over a precipice of 76 feet in height. This is the fifth and "Great fall" of the Missouri. The banks are high and abrupt on both sides, and above and below deep ravines, with bare, steep sides, extend out into the prairie from 1 to 2 miles. But opposite the fall, and on the north side, a narrow tongue of waving prairie runs near to the river, and breaks off in terraces to a small bottom below the cascade. The lower plain, embracing two or three acres, is a rounded point of land, which, with a rock-bound shoulder, half encircles the basin of the cascade, and for a short distance below confines the water-course to half its usual width. Near its head a broken and disconnected ledge of rocks rises some 30 feet or more above the water, but lower down there is some soil and a few scattered cottonwood, willow, and cherry trees.

For miles below its falls the course of the Missouri lies through a deep cañon; as far as the mouth of Maria's river its banks are 100 to 160 feet high, and it flows clear and transparent over a gravelly bed, with a current of about 2.7 miles an hour. From Fort Benton the general direction of the river is, for eight degrees of longitude, easterly along the forty-eighth parallel, from which it nowhere departs more than about 40 miles. In this distance the principal tributaries which it receives are, in order, the Musselshell, Milk, and Yellowstone. Below the mouth of Maria's river the banks of the Missouri are less abrupt, and rise by gentle slopes to the bluffs. From Fort Benton to Carroll, a distance of 167 miles, the river is rapid, with fixed channel and stable banks. The bed is largely composed of gravel, with numerous bowlders. The river now begins to change its character, and for 120 miles is intermediate between the rocky and rapid stream which it has previously been, and the shifting sand-bar river which it then becomes and continues to be for the remaining 215 miles to the mouth of the Yellowstone, and thence to the Mississippi. Its high-water width, which in the vicinity of Fort Benton is 500 to 1,000 feet, increases to 1,500 feet at the mouth of Milk river, and to 2,000 feet below the mouth of the Yellowstone.

The latter stream, almost the peer of the upper Missouri, deserves description. The upper Yellowstone has its source in northwestern Wyoming, a little below the parallel of 44°. It pursues a short course of 40 or 50 miles, and then enters the renowned Yellowstone lake, which may be considered the great source of the main river. The Yellowstone National Park occupies the northwestern corner of Wyoming territory. It is 65 miles long by 55 wide, and within its area, nearly half as large as the state of Massachusetts, embraces most wonderful scenery. Dr. Hayden says that the whole region was, in comparatively modern geological times, the scene of the most wonderful volcanic activity of any portion of this country. Here are seen great mountains, yawning cañons, and remarkable geysers and hot springs. A little southeast of the center of the park lies Yellowstone lake, about 20 miles long and 15 miles wide. Its shore line, which is rough and irregular, is said to measure 175 miles in length.

The lake lies at an altitude of 7,778 feet above the sea, and is, in places, nearly 300 feet deep. It is hemmed in on every side by lofty mountain ranges, and from the melting snows on their slopes its chief supply of water must come, since it receives no important tributaries.

In the early part of the day, when the air is still and the bright sunshine falls on its unruffled surface, its bright green color, shading to a delicate ultramarine, commands the admiration of every beholder. Later in the day, when the mountain winds come down from their icy heights, it puts on an aspect more in accordance with the fierce wilderness around it. Its shores are paved with volcanic rocks, sometimes in masses, sometimes broken and worn into pebbles of trachyte, obsidian, chalcedony, cornelians, agates, and bits of agatized wood; and again, ground to obsidian sand sprinkled with crystals of California diamonds.

Only 10 or 15 miles from the lake occur the Great Falls of the Yellowstone. In 1875 Captain William Ludlow explored this portion of the Yellowstone valley, and thus described the Upper fall:

Reserving the Lower fall, whose deep thunder we could now plainly hear, we descended toward the Upper, and after a short scramble over loose trachytic blocks, climbed out upon a point which, projecting into the cañon below the fall, furnished a fine view of it almost *en face*. The river makes a sharp bend to the eastward just above the fall, which in consequence fronts nearly at right angles to the general direction. From the sharp and narrow pinnacle on which we stood, or rather to which we clung, the cataract, some 150 feet distant, was exposed in its full height and beauty. It is a slanting one, having a base of, perhaps, one-half its altitude, which, as measured by a cord brought for the purpose, and marked in 10-foot lengths, is 110 feet. The water leaps down its rocky slope between black, shining walls of trachyte, and its pure green is broken into foam and spray from the very summit. From the foot the currents of air drove the clouds of vapor up the steep sides of the cañon, which were clothed in vegetation of the freshest and most brilliant hue, while a double rainbow illumined the surface of the stream below.

The Upper fall is only a quarter to a half mile from the Lower; of this Captain Ludlow says:

The view of the Grand cañon, from the point where we stood, is, perhaps, the finest piece of scenery in the world. I can conceive of no combination of pictorial splendors which could unite more potently the two requisites of majesty and beauty. Close at hand the river, narrowed in its bed to a width of some 70 feet, and with a depth of 4 to 5 feet, through the pure deep green of which the hardly wavering outlines of the brown bowlders beneath are distinctly visible, springs to the crest with an intensity of motion that makes its clear depths fairly seem to quiver. Just before making the plunge the stream is again contracted, and the waters are thrown in from both sides toward the center, so that two bold, rounded prominences or buttresses, as it were, are formed where green and white commingle. Lying prostrate and looking down into the depth, with the cold breath of the cañon fanning the face, one can see that these ribs continue downward, the whole mass of the fall gradually breaking into spray against the air, until lost in the vast cloud of vapor that hides its lowest third, and out of which comes up a mighty roar that shakes the hills and communicates a strange vibration to the nerves. The height of the fall, as ascertained by attaching a heavy weight to the measured cord and lowering it down, is 310 feet.

From the falls the river passes for 20 miles through the Grand cañon. This is impassable throughout, and at only a few points can the water's edge be reached; no sound comes up from its profound depth. Eighty miles, more or less, to the northward from Yellowstone lake the river issues from the Snow mountains, and then runs to the east and northeast till it joins the upper Missouri at Fort Buford, only a few miles on the Dakota side of the boundary between that and Montana territories. On emerging from the mountains the river is 600 feet wide and 6 feet deep. Thence to the mouth of Clarke's fork it is characterized by many islands and bold sweeping curves. Between Clarke's fork and the Big Horn it is 1,500 to 1,800 feet wide, free from rapids, and has a current of 3 to 4 miles an hour. The Big Horn river rises in the mountains some 30 miles south of the southeastern corner of Yellowstone National Park. For 100 miles by general course it flows in quite a direct course toward the southeast; but in the vicinity of latitude 43° north, and longitude 108° 30′ west, it turns abruptly northward, and though down to this point it has been known as Wind river, thence to the Yellowstone it is called the Big Horn. The length of the Big Horn, to the source of Wind river, is about 330 miles by general course, and it has a drainage area of about 22,360 square miles. From the Big Horn to Powder river the Yellowstone increases in width to from 2,400 to 2,700 feet, and becomes turbid like the Missouri. From Powder river to the Missouri the banks are low and caving, and the stream contains numerous sand-bars, densely-timbered islands, with some rapids and shoals.

The mouth of the Yellowstone is, according to Captain Raynolds, 1,894 miles above the mouth of the Missouri. Upon reaching the confluence of the Yellowstone and the upper Missouri, Lewis and Clarke measured the two streams with the following result:

Just above the confluence we measured the two rivers, and found the bed of the Missouri 520 yards wide, the water occupying only 330, and the channel deep, while the Yellowstone, including its sand-bar, occupied 858 yards, with 297 yards of water; the deepest part of the channel was 12 feet, but the river is now falling and seems to be nearly at its summer height.

From the point of junction, the Missouri follows a winding, but, on the whole, southeasterly course, passing over very nearly nine degrees of latitude, till it reaches the mouth of the Kansas river, in latitude 39° 6′; it then takes a more easterly direction across the state of Missouri, and empties into the Mississippi river 16 miles above Saint Louis, 189 above the mouth of the Ohio, and 2,824 miles below the point where it was formed by the union of Jefferson, Madison, and Gallatin forks. Below the Yellowstone the width continues quite uniform; from 2,000 feet it gradually increases to 3,000, which remains approximately its average width for the last 600 miles of its course. Six hundred and forty miles from the mouth it receives the Platte river, and again, 258 miles below, is joined by the Kansas.

The tributaries entering the Missouri below Fort Randall will hereafter be described in detail; the accompanying table gives the names of all the more important ones, in order from the headwaters of the main river, and their drainage areas:

Tributaries of the Missouri river.

Stream.	Drainage area.	Stream.	Drainage area.	Stream.	Drainage area.
	Sq. miles.		*Sq. miles.*		*Sq. miles.*
Jefferson fork	9,188	Powder river (to Yellowstone)	15,525	Little Sioux river	4,233
Madison fork	2,823	Little Missouri river	7,663	Platte river	90,407
Gallatin fork	1,728	Big Knife river	1,892	Nishnabatona river	3,100
Smith's river	2,004	Big Heart river	3,039	Nemaha river	1,924
Teton river, above Maria's	2,640	Cannon Ball river	4,244	Nodaway river	1,886
Maria's river, above Teton	7,556	Grand river	6,412	Platte river (of Missouri)	2,487
Judith river	2,524	Moreau river	4,633	Kansas river	59,757
Musselshell river	10,500	Big Cheyenne river	24,117	Grand river	7,932
Milk river	26,700	Bad river	3,059	Chariton river	2,900
Poplar river	3,508	White river	10,244	La Mine river	2,700
Big Muddy river	3,768	Niobrara river	13,200	Osage river	15,262
Yellowstone river	67,475	Dakota river	22,000	Gasconade river	3,667
Big Horn river (to Yellowstone)	22,360	Vermillion river	2,230		
Tongue river (to Yellowstone)	3,695	Big Sioux river	7,880		

Of the streams above the Niobrara I have but little information; of those below, only one, the Osage, is navigable at low water. Boats of 2-feet draught can ascend that river for about 50 miles. The Gasconade may be navigated at high water, and it is considered that both this river and the Kansas might be so improved as to be of value at low stages, though the expense involved would be considerable.

For information more directly concerning the physical features of the Missouri river I am indebted to the preliminary report by Major Charles R. Suter, Corps of Engineers, United States Army, who speaks as follows of the immediate valley:

> The main valley of the river consists of a great rock trough, from 1½ to 17 miles in width, cut down from the general level of the country to a depth considerably below the present level of the valley. The rocky banks form bluffs along the stream, and the bed is also of rock. This great trough seems to have been filled at one time with the Glacial Drift deposits, which also cover the adjacent country, and subsequently in part cleared out by the great river that probably occupied it in the early Post-Glacial times.
>
> The Drift deposits seem everywhere pretty well sorted out, bowlders are generally found next the rock, and deposits of varying degrees of coarseness above. The main feature is the great preponderance of extremely fine sand, which, with the addition of a very small amount of alumina, forms an extremely tenacious clay, locally known as "gumbo", and which is met with everywhere, and is formed in the bed of the stream wherever the current is unusually slackened. Large beds or pockets of very coarse gravel or pebbles are also met with in borings at different depths below the surface. They are usually water-worn fragments of quartz, mostly red and yellow jasper. The general absence of the large, high, and well-defined terraces which are usually found in valleys of this description, and the general prevalence in the surface soil of the very fine sand before alluded to, leads to the inference that the river, within comparatively recent times, has scoured over the greater part of the area embraced between the limiting bluffs, at least in the narrower portions of the valley.

From the report on founding piers for the Saint Joseph bridge, made by the engineer, Mr. W. S. Pope, it appears that the material through which the piers passed was, in general, fine sand or silt. Pockets of "gumbo" were met with, and snags and driftwood were of frequent occurrence. At a depth of 40 feet below the river-bed fragments of brick and pieces of coal were found. Usually the bed-rock was immediately overlaid by a deposit, 2 to 5 feet thick, of medium-sized bowlders and coarse sand. The bowlders were red and gray granite, schist, gneiss, conglomerate, trap, and quartz. The bed-rock was found to be a smooth, hard, whitish-gray limestone, overlaid with a broken shale 2 or 3 inches thick. While the Missouri river water is generally turbid, that found coursing along through the bottom deposit was pure and clear as spring water. Even when the ice was 2 feet thick on the surface, and the mercury was below zero, this water had a uniform temperature of 54° Fahrenheit.

The immediate bed of the river is of the most treacherous character. At the site of the Atchison bridge it was found to be composed of sand and gravel, and to be very shifting. The pivot pier was surrounded by sand to a depth of 35 feet, till in July, 1879, this deposit was entirely swept away, leaving the pier bare down to bed-rock. I was informed that, during the construction of the bridge, piles were sometimes driven one day in sand which was 25 feet deep, but which entirely disappeared within twenty-four hours.

Except in the mountain cañons the course of the Missouri lies through alluvial bottom-land of the most fertile character, and varying in width from 1½ miles near the mouth to 17 miles in the vicinity of Sioux City. In some places the bottom is apparently on a dead level; in others it has been cut up by high-water chutes, and frequently contains lakes which have resulted from cut-offs or changes in the course of the river; not uncommonly the immediate banks of the stream are found to be somewhat higher than the adjoining bottom, so that there is a downward slope from them in toward the bluffs. Through its alluvial flood-plain the river winds back and forth

from one bluff to the other, thus leaving tongues of land, which alternately reach out from one bluff to within a few thousand feet of the opposite. In the vicinity of Saint Joseph the Missouri is said to make eight complete crossings of the valley within a distance of 30 miles, measured in the direction of its general course.

The following table, furnished me by Major Suter, shows the width of the Missouri valley at various points, as measured between the bases of the bluffs:

Widths of the Missouri River valley.

Locality.	Average width.	Maximum width.	Minimum width.
	Miles.	*Miles.*	*Miles.*
Sioux City to a point 8 miles above Florence, Douglas county, Nebraska	10.54	17.00	7.00
Thence to a point 8 miles above Amazonia, Andrew county, Missouri	4.25	5.30	2.75
Thence to Kansas City	2.64	3.80	1.70
Thence to Glasgow	3.47	5.02	2.27 1.80
Thence to mouth	2.00	3.10	1.50

From the mouth of the James to the "Big Bend", where the Missouri crosses the forty-eighth parallel, the average width of the bottoms is only 1 to 2 miles. Of this part of the river Humphreys and Abbot spoke as follows:

> The Hupan-Kutey prairie, lying between this stream (the Big Sioux) and the Vermillion, is low and fertile, and is about the last of the continuous fertile country as you advance up the Missouri, which here comes from the west. Above this (to the upper big bend) the bottom-lands of the Missouri are sometimes 1 and 2 miles wide, and will give but precarious support to an agricultural people; it is doubtful whether even this can be said of the higher prairie lying back from the stream.

Above the "Big Bend" the valley widens somewhat, and up to a point 50 miles above the mouth of the Yellowstone has an average width of 3 to 6 miles.

The following table, giving the elevations and slope of the Missouri, is copied from Humphreys and Abbot's report:

Low-water slope of the Missouri river.

Locality.	Distance above the mouth.	Elevations above the Gulf.	Fall per mile.	Authority.
Big Horn branch.	*Miles.*	*Feet.*	*Feet.*	
Source (Wind river)	2,565	7,527	.....	Captain Raynolds.
Mouth of Popo Agie	2,450	5,347	18.96	Captain Raynolds.
Leaves Big Horn mountains	2,231	3,534	8.22	Captain Raynolds.
Mouth of Big Horn	2,159	2,831	9.78	Captain Raynolds.
Yellowstone branch.				
Source (lake)	2,439	(?) 6,500	.....	Captain Raynolds.
Leaves Snow mountains	2,345	4,705	19.10	Captain Raynolds.
Mouth of Big Horn	2,159	2,831	10.08	Captain Raynolds.
Mouth of Yellowstone	1,894	2,188	2.43	Captain Raynolds.
Upper Missouri branch.				
Source of Madison Fork	2,908	(?) 6,800	.....	Captain Raynolds.
Three forks of Missouri	2,824	4,319	29.52	Captain Raynolds.
Mouth of Sun river	2,689	3,573	5.54	Captain Raynolds.
Foot of falls	2,670	2,964	31.59	Captain Raynolds.
At Fort Benton	2,644	2,845	4.56	Captain Raynolds.
At Fort Union	1,894	2,194	0.88	Captain Raynolds.
At Fort Pierre	1,246	1,475	1.10	Lieutenant Warren.
At Sioux City	842	1,065	1.01	Railroad levels.
At Saint Joseph, Missouri	484	756	0.86	Railroad levels.
At mouth	.....	381	0.77	Railroad levels.
*Additional elevations.**				
Yellowstone at Glendive, Montana	.....	2,045	.....	Average low water, Northern Pacific railroad levels.
Little Missouri at Northern Pacific crossing	.....	2,245	.....	Average low water, Northern Pacific railroad levels.

* Not taken from Humphreys and Abbot's report.

The volume of the Missouri is subject to great variations, the ordinary high-water discharge at the mouth being about twenty-eight times that at low water. There are two causes of the freshets in this river—melting snow, and heavy summer rains. The amount of snow falling on the prairies is usually quite small, and in some

winters is scarcely worth mentioning, but amid the Rocky mountains snows begin early, continue late, and accumulate to great depth. As to the effect of this body of snow upon that portion of the Missouri above Milk river, Lieutenant Grover wrote:

The fact of this part of the river lying near its sources in the Rocky mountains would naturally lead one to suppose that the changes in its volume of water from month to month would be nearly the same, for the same month, from year to year. This is found to be the case. As winter breaks up and warmer weather gradually comes on in the spring the ice becomes rotten, and the river is swollen by the melting of snow in the valley, and as early as the 1st of May the river is clear. Such is the great range of elevation, and, consequently, the great range of temperature, covered by this feeding reservoir of snow, that instead of melting in the short space of a month and swelling the river to a torrent, the process of melting commences with the valleys in the early spring, and goes on gradually to higher elevations as the season advances, constantly diminishing, of course, till August, when all that has a sensible effect upon the river is expended, when it commences falling more rapidly till the latter part of September.

The upper Missouri, the Yellowstone, the Big Cheyenne, and the Platte are the streams mainly affected by melting snow.

For a period of about two months, beginning in different years from the middle of May to the last of June, heavy local rains occur. The rainfall is sudden and violent, and frequently accompanied by thunder and lightning. During this period, the monthly rainfall is sometimes three or more times the average monthly rainfall for the year. From the widely extended, open, and, to a large extent, uncultivated, drainage-basins of the streams, floods of water pass down their channels and find their way into the Missouri, already raised by melting snows. At this season occurs what is termed the "big rise" or the "June rise".

Major Suter states, concerning the Missouri floods, in his preliminary report:

The regular floods are two in number, and usually occur in April and in June. The first is extremely violent and of short duration, rarely lasting over a week or ten days; it seems to come largely from the upper river. The June rise, although generally higher, is of longer duration, being influenced by local rains and the general saturation of the soil. It is followed by a steady fall, which continues with considerable regularity till the freezing weather closes the small affluents as well as the upper river; then a sudden fall of 3 or 4 feet takes place, and the river reaches its winter level. There are occasional small rises of short duration besides those mentioned; one, especially, usually occurs late in the fall, but the two first mentioned, are, from all points of view, the most important.

Humphreys and Abbot give the range between high and low water in the Missouri as about 35 feet at the mouth, 20 feet at Saint Joseph, and only 6 feet at Fort Benton. The greatest recorded freshet in the lower river was that of 1844, although the rise of that year was somewhat exceeded temporarily at points on the upper river during the spring of 1881.

For the first 350 miles below the union of the Three Forks the Missouri is comparatively a clear stream, but in the vicinity of Carroll, Montana, approximately midway between the forks and the Yellowstone, its character gradually changes, and it becomes turbid. A similar change takes place in the Yellowstone below the mouth of the Big Horn, perhaps 250 miles above the Missouri. Although from the mountains the Missouri undoubtedly receives a large amount of sediment, especially that of the feldspathic and aluminous composition, yet it is mostly below the limits above given that it acquires its muddy appearance, which is due to the caving in of its banks.

To understand this action it is necessary to bear in mind the nature of the banks. An examination of the Saint Joseph river-front, in the vicinity of the bridge, by government engineers, showed the bank to be about 25 feet high at low water; it was composed of hard clay, not affected by the current. This material extended down 16 feet below low water, and at that depth was underlaid by 8 feet of quicksand; below this, clay, sand, gravel, and bowlders extended to bed-rock. This is but a single case, yet it probably illustrates the general character of the river banks throughout that part of the valley which we are considering. It is thought probable that in a rising stage the sediment carried by the Missouri is mainly brought in by the drainage of its tributaries. During that stage the banks become saturated with water, their cohesion is lessened, and at the same time they are being undermined by the washing out of the underlying strata of quicksand. As soon as the river begins to fall and uncover the banks they are filled with deep mud cracks, the sustaining pressure of the water is removed, and they are constantly caving in, a foot or two at a time, and sometimes in much greater masses. In this manner is supplied the larger part of the sediment belonging to a falling stage.

This action goes on with great rapidity, and during a single year the river may encroach 1,000 to 2,000 feet upon its banks. It is estimated that between Sioux City and the mouth of the Missouri the banks cave in, on the average, at the rate of 20,000,000 cubic feet per mile in the course of a year. A single illustration will show the speed with which erosion occasionally goes on. On July 8, 1877, a cut-off took place at Omaha, which resulted in throwing the river with great force against the Omaha bank. In his December report for that year Mr. Max Boehmer, United States assistant engineer, stated that in a short time, the exact length of which was not mentioned, the river had eaten into the bank a distance of 1,200 feet, till farther advance was stopped by throwing in sand-bags, stone, and brush, and by the construction of a revetment 2,000 feet long.

The Missouri now affords continuous navigation from its mouth to Fort Benton, in Montana territory, a distance of more than 2,600 miles; passing above Fort Benton we find it again navigable beyond the Great falls. But in speaking of the river as navigable below Fort Benton, it must not be understood that it is throughout this distance, or at all seasons of the year, favorable to such use, for that is not the case. In extremely low water there is not

much navigation on the lower river above Kansas City, less than 400 miles from the mouth, and even over that distance it is difficult. On the upper river considerable freighting is done to and from Fort Benton of government supplies, furs, hides, wool, and cattle.

On the lower river the principal hindrances to navigation are snags and shifting bars. The banks are generally timbered, and since they are so constantly caving in, especially during high water, they carry with them a great many large trees, which speedily sink and become imbedded in the river bottom, rendering safe progress for boats at night out of the question. During freshets the tributaries of the Missouri bring in a great deal of miscellaneous floating drift. I was informed that at the Kansas City bridge this sometimes lodges in masses against the piers, rapidly accumulates, and, if not broken up, is liable to dam up the river even more effectually than an ice-gorge. As we advance up the river, however, less and less timber appears upon its banks, and above the mouth of the James there are comparatively few snags.

The important cities which have sprung up on the banks of the Missouri, and the agricultural interests which have developed in its great valley, have alike demanded that some action should be taken toward the control of so dangerous a stream; and within the past few years considerable sums have been spent by the general government, mainly for the protection of threatened points. The work has been to some extent experimental, but very successful, and remarkable results have been brought about by the very simplest contrivances. The difficulties and great expense attending improvements carried on at a few remote points on the river, where the work is usually of very limited extent, and the advantages to accrue to the whole valley by its proper protection from the encroachments of the river, have led to the design of a general improvement of the Missouri below Sioux City. The points which are sought to be insured by this plan are, as stated by Major Suter:

> At any stage, equality of cross-section both in width and depth, uniformity of slope, and, in consequence, uniformity of velocity, while the channel at all stages shall be permanent in location.

Major Suter considers that from Sioux City to the mouth, a distance of about 800 miles, a uniform navigable depth of 12 feet at lowest stages can be guaranteed. It is estimated that, if this work be undertaken upon a sufficiently large scale, it may be completed for the above distance at a total expense of $8,000,000, or $10,000 per mile, the improvement to progress at the rate of about 100 miles a year.

As to the value of the Missouri river for water-power I can say but little. The upper portion of the stream, where it lies among the mountains, doubtless presents opportunities for realizing great power, though it is inaccessible, and no present demand exists for it. My visits to this river did not extend above Yankton, and it is evident that over the navigable portion of the Missouri the obtaining of useful power by any ordinary methods is not to be thought of. It has frequently been suggested that upon many of the rapid western rivers, such as the Missouri, Platte, Loup, and Elkhorn, paddle-wheels, supported upon barges moored in the current, might be used for power. I have not, however, met with any such device in operation, though there is a rumor of one having at some time been used in the Missouri at Sioux City. Weisbach gives the theoretical delivery of a paddle-wheel 15 feet high, with 8 floats, each 12 feet by 1 foot in the water, the latter having a velocity of 5 feet per second, to be 614 foot pounds per second, or a little more than one horse-power. The speed of the Missouri river current varies, in different localities and stages, from about 3 feet to 10 or 15 feet per second; but though it is possible to obtain small powers with some such contrivance as indicated above, still the results are too slight, and the practical disadvantages too great, to admit of their extended use.

Drainage areas of the Missouri river.

[Measured on General Land Office maps.]

Locality.	Square miles.	Locality.	Square miles.
Junction Three Forks of the Missouri river	13,739	Sioux City	313,183
Fort Benton	23,215	Above Platte river	322,500
Dauphin Rapids	39,439	Below Platte river	412,907
Below Milk river	86,291	Above Kansas river	426,893
Above Yellowstone river	98,910	Below Kansas river	486,650
Below Yellowstone river	166,385	Above Osage river	505,721
Bismarck (above Big Heart river)	188,084	Below Osage river	520,983
Fort Randall	263,651	Mouth of Missouri river	527,155

Summary of observations on discharge of the Missouri river at Saint Charles, for the year 1879.

[Measurements made under the direction of Major Charles R. Suter.]

Month.	Total discharge in cubic feet.	Average daily discharge in cubic feet.	Average discharge in cubic feet per second.	Average discharge in cubic feet per second per square mile of drainage area.*
January	91,787,040,000	2,960,872,258	34,269	0.06503
February	86,550,299,600	3,091,082,129	35,776	0.06789
March	109,479,686,400	3,531,602,787	40,875	0.07756
April	278,837,942,400	9,294,598,080	107,576	0.20413
May	206,505,936,000	6,661,481,807	77,100	0.14630
June	413,716,291,200	13,790,543,040	159,613	0.30287
July	481,738,838,400	15,539,962,529	179,861	0.34129
August	225,546,259,600	7,275,685,793	84,209	0.15979
September	100,480,694,400	3,349,356,480	38,766	0.07356
October	80,238,843,200	2,588,349,781	29,958	0.05685
November	133,690,867,200	4,456,362,240	51,578	0.09787
December	126,571,248,000	4,082,943,484	47,256	0.08967
Total	2,335,143,946,400	6,397,654,648	74,047	0.14051

* Drainage area assumed at 527,000 square miles.

III.—TRIBUTARIES ON THE EAST SIDE OF THE MISSOURI RIVER, BELOW YANKTON.

In describing those rivers which are tributary to the Missouri on the east, I shall consider the more important ones in order, beginning with the Dakota and ending with the Chariton. Above the former stream the country is but little developed at present, while below the Chariton no accessions of any consequence are received from the left.

THE DAKOTA RIVER.

Taking its rise in Gingras county, in northern Dakota, this river flows over a long and crooked course having a general bearing to the south, and finally reaches the Missouri about 9 miles east of Yankton. It is said to have been called *Rivière Jacques* by early French traders, a name which became, in English, James river, and by which it is still commonly known, although its name has been declared by law to be the Dakota river. Its source is distant but a few miles from the headwaters of the Cheyenne, which empties into the Red River of the North. Its basin stretches thence to the southward through five degrees of latitude, and is 340 miles long, with a width varying from 60 to 90 miles. The area included within its water-shed lines I estimate as about 22,000 square miles; but the topography of this region is so little known, and so slightly represented on maps, that these figures cannot be considered very accurate. Following the general course of the river, and neglecting the lesser curves, its length is 415 miles; but if all the curves were taken into account, by accurate meandering, it would doubtless appear two or three times as long. In Dakota it is popularly regarded as the longest river in the world that has no natural capabilities for navigation.

The greater part of this river is so difficult of access, that I have been able to obtain but little information in detail concerning either its own features or those of the valley and surrounding country. This region was evidently once covered by glaciers, and the line of a terminal moraine, passing down between the Missouri and Dakota rivers, crosses the lower course of the latter. Deposits of drift material are displayed along the river, and appear also upon the face of the surrounding country, though not to such an extent as to interfere with its cultivation. A great many small lakes are to be seen, which were probably left when the glaciers had receded; some of these drain into the Dakota river, but most are apparently isolated. Within 30 miles of the river there are numerous little creeks which find their way into it, but they are of no consequence, and during fall and winter many of them run entirely dry.

The valley of the main stream has been discovered to be of great fertility, well adapted to the production of wheat and corn, and within a year or two has attracted a considerable immigration. Still this section is but sparsely settled, and the combined population of all the counties directly bordering the river is only about 23,000; and 80 per cent. of this number is confined to the six lower counties. Mitchell, on the lower river, and Jamestown, on the upper course, are two of the most important places. Lines of railroad already cross the stream at various points, and are pushing on to the westward. A north-and-south line is being built along the valley, and from Jamestown the Northern Pacific Railroad Company is extending a branch to the northwest, toward Mouse river.

Although the Dakota river is not naturally navigable, it is considered by some that slack-water navigation is practicable, especially toward the mouth. In consequence of a dam at Columbia, slack water is caused for a long distance above, and small boats are enabled to use that portion of the river, during a part of the year, as far north as Grand Rapids, some 70 miles by general course above Columbia. In 1874 an examination of the river was made by a government engineer. (*a*) The stream was found to be so tortuous, and to carry so small a volume of water, that improvement of the natural channel by ordinary methods was not thought practicable; it also seemed doubtful whether, by damming the outlet of lake Tchanchicaha, sufficient water could be stored even to supply a canal.

The immediate course of the river lies through bottom-land, which is sometimes gently rolling and gravelly, and again flat and marshy. From the bottom-land there is a gradual rise to the bluffs, which are low; and beyond these stretches the open prairie. In the vicinity of Jamestown, and for 40 miles below, there is a slight fringe of timber along the stream; but over the greater part of the country drained by the Dakota none of any importance appears. Along the course of the stream there are several lakes, which are merely widenings-out of the channel; two of these occur 25 miles north of Jamestown and have received the names of Arrowwood and Jim lakes. Each is about 6 miles long, half a mile wide, and with banks 20 to 40 feet high. They might be of some value for storage, but it is said that if they were to be raised by a dam the structure would need to be 1,200 or 1,300 feet long.

The Northern Pacific railroad crosses the river at Jamestown, county-seat of Stutsman county. A small power is used at this point by a flouring-mill; the dam is of crib-work, with brush and stone filling, and gives a head of 9 feet. In summer the river is 25 or 30 feet wide here, and the privilege is considered good for 40 horse-power; but in winter the width is only 10 or 15 feet and the supply of water is so small that the water-power is worthless. The banks are about 10 or 15 feet high above low-water, and are the same at Grand Rapids. Between Jamestown and the latter locality the river has a fall of 100 feet or more, with no sites improved, though it was reported that work on one dam had been begun. From the government engineer's report, previously alluded to, it appears that from a point distant 3 miles below Jamestown a chain of rapids extends for 9 miles, with a fall of 54 feet. From this section down to the vicinity of Grand Rapids there are numerous riffles; some of these are 2 miles or more in length, and one has, for 4 miles, a fall of 12 feet per mile. From Jamestown to Grand Rapids the river-bed is composed of sand, gravel, and bowlders, and the banks range in height from 10 to 18 feet. The volume is small at low-water, but flouring- and grist-mills of moderate size could probably run during the greater part of the year.

At Grand Rapids a dam 9 feet high has been built of brush and gravel in alternate layers; but the power is not yet in use. Below Grand Rapids the river is very sluggish, and has but a slight descent. General W. H. H. Beadle, of Yankton, says of the portion lying above Columbia:

> I have surveyed public lands at various points for 80 miles below Jamestown, and have traveled along the Dakota (James) river from Yankton to Jamestown several times in 1873 and since. In my surveys I have had occasion to cross the river by wading it in probably thirty places between Grand Rapids and Columbia. Speaking of that region especially, from a short distance below Grand Rapids to Columbia—some 60 miles by road and 120 by river—there is practically no fall to the river. I have measured the width of water in twenty or thirty places, and it is from 2½ to 4½ chains wide, or from 160 to 300 feet—nowhere narrower than 150 feet, I believe. Its depth is very uniform, about 3½ feet in July, August, and September, the dry season. In places it is 5 or 6 feet deep.
>
> The banks are usually the black loam and clay of the bottom-lands, though in places they are higher and more solid and dry. Heavy grass grows on them and very often down into the water from 5 to 15 feet. This part of the river and generally near the banks is muddy, a man sinking easily 8 to 12 inches in it, but in the middle of the stream, for a width of 60 to 100 feet, the bottom is firm and often hard, apparently sandy, on the surface at least. A dam at Columbia would back the water nearly to Grand Rapids; a dam elevated 12 feet would back it above Grand Rapids. That rise would fill the banks in most places and overflow some low ground, not so valuable for any other purpose. The surface of water obtained by a dam 12 or 15 feet high at Columbia would reach, including the so-called lake above Columbia, an area of 15 or more square miles, and would afford a vast storage for water to be used at the dam and at numerous mill-sites 200 miles below to the Missouri river.

The river continues sluggish throughout the remainder of its course. The bed is generally muddy, but there is an outcrop of sandstone at Rockport, and it is reported that both sandstone and limestone appear 20 miles above. No power is used except by a few flouring- and grist-mills below Mitchell. Between that point and the mouth of the river a total fall of 38½ feet is returned as thus employed, probably leaving but little of the descent of the stream unimproved. The dams average perhaps 100 feet in length by 8 in height, and are of varied construction; in some cases framed, while in others they are rudely built of stone and backed with earth.

No continuous line of levels has been run along the course of the Dakota river. Railroad surveys show the river surface at the Northern Pacific crossing to be 1,385 feet above the sea; and at the Chicago and Northwestern crossing, in Beadle county, 1,228 feet above the sea. By map measurement the intervening distance is 252 miles, in which there is thus a descent of 157 feet, or an average of 0.62 foot per mile.

The rainfall over the basin of this river may be taken as approximately 6 inches in spring, 10 in summer, 3 in autumn, and 2 in winter, making a total of 21 inches for the year. No measurements have been made of the volume of the stream, and it cannot be estimated with much accuracy. For low stages, however, the rate of discharge probably lies between 0.01 and 0.02 cubic foot per second per square mile of drainage area.

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a See *Report Chief of Engineers*, 1874.

Estimated volume and horse-power of the Dakota river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 8 TO 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.									
Jamestown	3,500	0.005	18	20	0.009	30	34	0.023	80	90
Grand Rapids	5,500	0.005	28	32	0.013	70	80	0.024	130	150
Columbia	10,000	0.007	70	80	0.015	150	170	0.025	250	280
Rockport	20,500	0.008	160	180	0.018	370	420	0.026	530	600
Mouth of river	22,000	0.008	180	430	0.020	440	500	0.028	620	700

THE VERMILION RIVER.

Two small streams, the East and West forks, unite in Turner county, Dakota, to form the main river, which then flows southerly to the Missouri. From the junction of the two forks to the mouth the distance by general course is about 45 miles. The drainage basin comprises an area of 2,230 square miles. Its surface is rolling, destitute of timber, and fertile from the bottoms of the valleys to the tops of the hills. Its value for agriculture has attracted a rapid settlement by people of various nationalities, including many Russian Mennonites.

The East and West forks are not more than 10 or 15 feet wide in an ordinary stage, and the average width of the main stream is probably not greater that 30 feet. It has very little value for power; there are a few flouring- and grist-mills, which obtain power for two or three runs of stone, but they are short of water part of the year, and are obliged to use steam in some cases. The volume of the stream is derived, not from springs, but from surface drainage, and hence, during the fall and winter, when the rainfall is light, there is but little water flowing—in fact, the East and West forks often dry up entirely, or become a mere chain of stagnant pools.

THE BIG SIOUX RIVER.

So far as concerns value for water-power, the Big Sioux is probably the most important tributary of the Missouri on the east; mainly because of its size, its rate of descent, and the large fall over rock ledges occurring at Sioux Falls. It rises 20 to 25 miles west of Big Stone lake, in the southern part of the Sisseton and Wahpeton Indian reservation, in Dakota. It runs southerly, nowhere more than 35 miles west of the Minnesota boundary, and reaches the Missouri river a short distance above Sioux City. The latter part of its course forms the division between Dakota and Iowa. The length by general course is about 210 miles, but the river is very winding and the true length is much greater. There is an exceptionally long bend at Sioux Falls, where, between points distant but 2½ miles in a straight line, the intervening distance by water is claimed to be 17 miles.

The area drained by the Big Sioux includes about 7,880 square miles. The surface is a rolling prairie, fertile, but almost entirely without timber. Scarcity of fuel is, indeed, an important defect in this section, and the settlers are sometimes compelled to resort to burning hay, sunflower stalks, and corn, as substitutes for coal and wood. The basin of the Sioux contains a great many Drift lakes, similar to those found in such large numbers in Minnesota; they are not seen below Sioux Falls, but above that locality are very numerous. Kampeska, Poinsett, and the Chain lakes are some of the most important ones. The latter are said to cover an area of 15 square miles, and Kampeska and Poinsett are still larger. The Drift lakes are usually of fair depth, and though in most cases they have no apparent inlet or outlet, still their waters do not become stagnant. They undoubtedly assist in maintaining the low-water volume of neighboring streams, by percolation through the ground. None of the lakes which drain into the Sioux are dammed, but the opinion was expressed by a surveyor well acquainted with the country, that all the larger ones might be thus improved, at a total expense of not more than $50,000, and rendered valuable as storage reservoirs. The evaporation from their surfaces must be very great. They lie in an open country, elevated 1,500 feet or more above the sea, and the brisk, dry winds, which are constantly sweeping over their surfaces, make heavy drafts on their volume.

The agricultural value of this region has invited a rapid settlement, and, according to the statistics of Mr. Henry Gannett, the population of the Big Sioux basin has increased from 6,173 in 1870, to 61,019 in 1880. This development has been fostered and hastened by constant railroad extension. At numerous points, well scattered along the whole course of the river, it is crossed by east-and-west lines, and a division of the Chicago, Milwaukee and Saint Paul road follows up the valley. The immediate valley of the stream is usually 1 mile to 3 miles wide, and above Sioux Falls is probably composed of modified Drift. In the lower course it is alluvial, and presents a wide, flat surface, bounded by distinctly defined bluffs. At Sioux Falls there is an interesting exposure of red Sioux

quartzite, which is said to appear at intervals to the eastward in Minnesota, and westward to the Missouri river. Possibly it was this, and not sandstone, which was reported to me as being found at Rockport, and points above on the Dakota river. There are also occasional outcropping ledges of rock at points on the river above Sioux Falls.

In Minnehaha county the Sioux is 100 to 150 feet wide, rapid and shallow, inclosed by banks 10 to 20 feet in height. In its lower course the average width is perhaps 200 feet, while the current is generally sluggish, varied now and then by riffles. The banks are of loam, except where, as at Sioux Falls and above, rock appears. The stream is well sustained by springs, and has a steady flow from month to month. It is not much affected by ordinary storms, and has only once overflowed its banks extensively in twelve years.

Elevations on Big Sioux river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Feet per mile.*
Watertown †	1,709			
		113	44	2.57
Near Brookings †	1,596			
		526	177	2.97
Mouth of river ‡	1,070			

* Map measurement. † Water surface at Chicago and Northwestern crossing. ‡ Estimated.

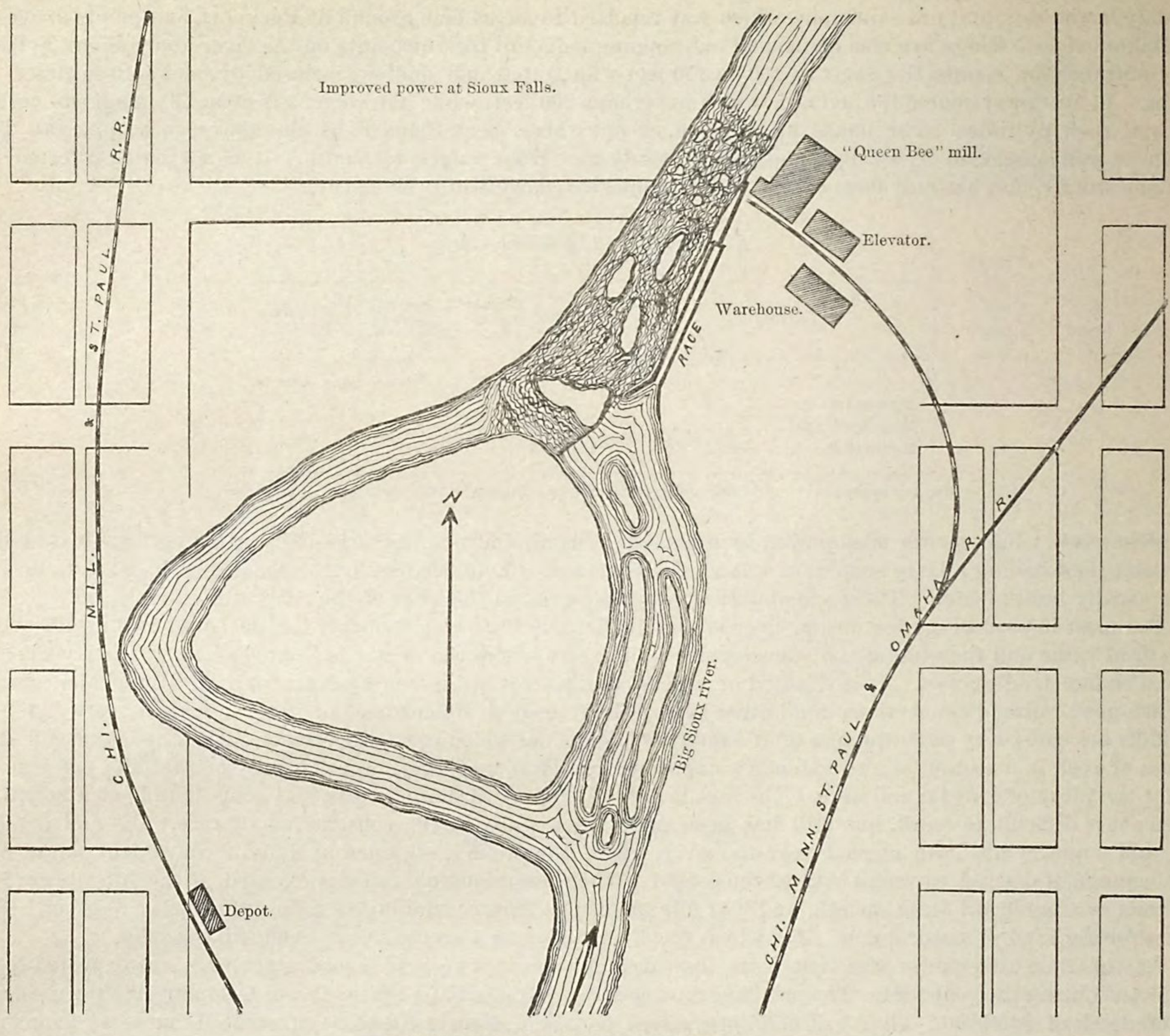
Below Sioux Falls power is employed by a number of small flouring- and grist-mills, carrying from two to four runs each, and having a large surplus of water. The dams are 150 to 300 feet long, about 8 feet high, and are said to be usually built of logs. There are doubtless available sites on this part of the river still unimproved.

The most important power on the river is that at Sioux Falls, which probably has no equal within 200 miles in natural value and thoroughness of development. The city where this power is located was but a few years ago a mere Indian trading-post. It is situated on a bend in the river in the southeastern part of Minnehaha county, and has good railroad connections in all directions. The river here descends 60 or 70 feet within a short distance. The falls are caused by outcroppings of red quartzite, ledges of which cross the stream. The appearance of such a mass of rock in a section where extensive exposures are rare, and the natural beauty of the falls, combine to render the place of note far and wide. The rock is so hard that it will scratch glass, and is susceptible of a beautiful polish; it is difficult to work, but still has been used successfully in the construction of race walls and a large mill, and a quarry has been opened near the river, where the stone is obtained in slabs of convenient shape, and large enough, if desired, to weigh several tons each. Where the Sioux quartzite is exposed, at the falls, its surface has been weathered till quite smooth, and it is full of vertical fissures running at right angles to each other. The ledges form a kind of natural dam, over which the river rushes in a succession of beautiful cascades.

At the time this power was visited its improvement was in a very advanced stage, and was expected to be completed during the year 1881. The privilege is owned by the Sioux Falls Water-Power Company, having a paid-in capital stock of $450,000. The work of improvement has been done in the most substantial manner. It has not been confined to the mere erection of a dam and provision of water and building-sites, but the design has been to provide everything—water, mill, and machinery—ready for use. To this end there has been built what is called the "Queen Bee" mill, at a cost of $200,000; it is 100 feet long, 80 feet wide, and seven stories high. It is strongly built, with thick walls of the hard quartzite already described; within are found the most recent improved kinds of machinery for the manufacture of flour, and all conveniences.

The present capacity of the mill is 600 barrels of flour a day, and it is claimed to have a possible capacity, when fully employed, of 1,200 barrels a day. At the time of my visit the rates to be charged for power had not been fixed upon. Adjoining the Queen Bee mill is a grain elevator with a capacity of 125,000 bushels. The shipping facilities are good, and spur tracks run directly to the mill.

As already stated, the rock ledges form a very good natural dam, and the only artificial addition necessary is a low framed structure, 70 feet long and 4 feet high. The descent of the river is so rapid that the pond will be small, covering but a few acres. From the head of the falls a race has been blasted out for about 200 feet, and flanked by heavy masonry walls. The race is 25 feet wide and 12 feet deep; at its extremity there is a bulkhead of masonry, pierced by two circular openings; from one of these a tubular iron flume, 7 feet in diameter, and made of No. 4 iron, weighing 683 pounds to the sheet, conveys water to the wheel-pit. The second opening in the bulkhead is now closed by a gate, but will be used in time for the entrance to another tube, to carry water for additional power. The head of water on the wheels is 56 feet 4 inches, and the privilege is claimed to be good for 1,240 horse-power (theoretical) in the ordinary stage of river, and for 2,000 horse-power many months in the year; about 300 horse-power will be used in the Queen Bee mill. The water-power company owns an additional fall of 14 feet below this one, which will not be used at present.



IMPROVED POWER AT SIOUX FALLS.

This section of Dakota is well suited to sheep raising, and though the power I have described has been developed mainly with a view to the manufacture of flour, it is hoped that there may be attracted to it establishments to engage in woolen and paper manufacturing. In the absence of any records of gaugings, I estimate the power available at Sioux Falls as follows:

Estimate of power at Sioux Falls.

Drainage area, 4,370 square miles.	Low water, ordinarily dry year.	Low water, average year.	Available ten months in average year.
Volume, cubic feet per second	70.0	110.0	180.0
Theoretical horse-power:			
1 foot head	8.0	12.5	20.4
10 feet head	80.0	125.0	204.0
56 feet head	450.0	700.0	1,140.0
70 feet head	560.0	875.0	1,430.0

A short distance above the water-power company's privilege is another, occupied by the Cascade flouring-mill. Four runs of stone are carried, the water-wheel being rated at 75 horse-power, and working under a head of 8 feet. There is water enough to run the mill at full capacity ten months in the year, and nearly at full capacity the

remainder of the time. The dam was built in 1877, and cost $4,500. It is a stone structure, 190 feet long and 5 feet high, and sets the river back for about 3 miles. There is another flouring-mill below the falls, but I have no particulars concerning the power.

Ascending the river, the next improved power above Sioux Falls is at Dell Rapids, 17 miles north, where there is a four-run flouring-mill, using about 40 horse-power, with 17 feet fall; the privilege is owned by Mr. William Van Epps, of Sioux Falls. A stone dam was built in 1878, at a cost of $2,000; it is 40 feet long, 14 feet high, and has a width of 14 feet at the base, decreasing to 7 feet at the top. Mr. Van Epps considers his privilege good for ten runs of stone ten months in the year.

The only mill above Dell Rapids, of which I could learn positively, was one at Flandreau, in Moody county; three runs of stone are carried there by a flouring-mill using 10 feet fall. The dam is mainly of brush and gravel, 68 feet long and 10 feet high; it is supplemented by an embankment 300 feet long and perhaps 5 feet high, the cost of the whole structure having been approximately $2,500. The river is set back so as to form a pond of about 100 acres, averaging 4 or 5 feet in depth.

There were reported to be one or two small grist-mills below Flandreau, either already built or in process of construction, but I learned no details regarding them. Only a small portion of the fall in this upper part of the river is yet improved. The locations of all the unoccupied sites can not be given, but I was informed by Mr. R. F. Pettigrew, of Sioux Falls, a gentleman who has surveyed along this section of the river, that there is a good unimproved privilege 2 miles above Flandreau, with 9 feet fall; four or five privileges, with about 10 feet fall each, between Egan (below Flandreau) and Dell Rapids; two near Sioux Falls, with stone ledges; and four or five below Sioux Falls, between that point and Canton. Generally speaking, a power may be developed every 3 or 4 miles, with an available head of ten feet. Above Flandreau there is hardly enough water for good powers, but by raising Kampeska lake, this section would be made valuable. That lake has an area of 28 square miles; it has a gravelly bed and is fed by springs. During high water, the Big Sioux sends part of its volume into the lake through a side channel, but as the river goes down it receives drainage from the lake through the same channel.

The rainfall on the basin of the Big Sioux river is about 7 inches in spring, 12 in summer, 4 in autumn, 2 in winter, and 25 for the year. I can learn of no gauging having been made on this stream, and therefore base my estimate of its volume upon a comparison with the Minnesota river. The country drained by the latter river above Judson is similar to that drained by the Big Sioux; the rainfall during the different seasons is also substantially the same over both districts. In the report by General G. K. Warren, Corps of Engineers, on the Minnesota river, (*a*) its low-water volume at different points is given as in the following table:

Low-water volumes of Minnesota river.

[Lowest observed, but not necessarily the lowest that there have been.]

Locality.	Drainage area.	Volume, cubic feet per second.	Cubic feet per second per square mile.
	Square miles.		
Foot of Big Stone lake	920	11	0.012
Above Pomme de Terre creek	2,620	42	0.016
Above Redwood river	8,540	217	0.025
Fort Ridgeley	9,850	253	0.026
Above Big Cottonwood river	10,190	307	0.030
Judson	11,940	397	0.033
Belle Plaine	16,380	1,575	0.096
Above Little Rapids	16,660	1,924	0.115
Mouth of river	17,230	* 1,155	0.067

* Observed November 25, 1867.

The basin of the Minnesota is a prairie region above Judson, but below that point soon becomes thickly wooded.

For the Big Sioux river I assume the rates of discharge to be:

(1) Low water of an ordinarily dry year, 0.016 to 0.018 cubic foot per second per square mile of drainage area.

(2) Low water of an average year, 0.025 to 0.027 cubic foot per second per square mile.

(3) Available ten months in an average year, 0.040 to 0.043 cubic foot per second per square mile.

a See Appendix J., *Report Chief of Engineers*, 1875, page 53.

The resulting volume and horse-power are as shown below:

Estimated volume and horse-power: Big Sioux river.

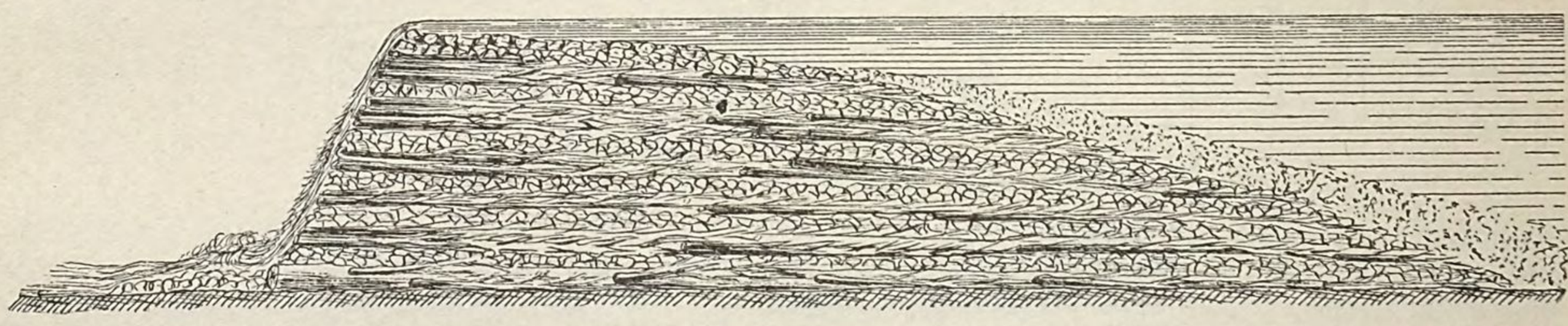
Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.									
Flandreau	3,270	0.016	50	60	0.025	80	90	0.040	130	150
Dell Rapids	3,560	0.016	60	70	0.025	90	100	0.042	150	170
Sioux Falls	4,370	0.017	70	80	0.026	110	125	0.042	180	200
Eden	5,300	0.018	90	100	0.026	140	160	0.043	230	260
Mouth of river	7,880	0.018	140	160	0.027	210	240	0.043	340	390

Of the tributaries of the Big Sioux, Split Rock creek, which comes in to the east of Sioux Falls, is used by a small grist-mill at Palisade, but carries scarcely enough water for that, and is of no importance.

ROCK RIVER.

This is the largest tributary. It rises in Pipe Stone county, in southwestern Minnesota, and, flowing southerly, runs across the northwest corner of Iowa and empties into the Big Sioux 45 miles, by general course, above its mouth. The bed and banks are generally sand and gravel, and display no ledges. The banks are low, and on one side or the other are frequently not more that 3 feet above low water. The stream is fairly steady; it rises, however, with the June rains and overflows its banks half a mile in width on each side. It commonly runs an average of 30 to 50 feet wide and 2 to 4 feet deep, with a moderate current.

Power is said to be used by flouring-mills at the following points: Luverne, one mill of two runs; Ash creek, one mill of two runs; Rock Rapids, two mills, each three runs; Rock valley (near the mouth), one mill of four or five runs. The dams are estimated to average 50 to 75 feet in length, 7 to 8 feet in height, and are in some cases constructed of brush. In building the latter, the bed of the stream is first covered with logs or trees having their branches on, the buts down-stream; upon these are added successive layers of brush and stone, and the interstices are filled with earth and manure. This style of dam is claimed to be durable and reasonably tight. The Luverne



SKETCH SHOWING CROSS-SECTION OF BRUSH DAM.

mill has a brush dam 45 feet long and 4½ feet high, which was built in 1878, at a cost of $200. The pond extends a mile and a half up the river. The mill is able to run at full capacity at least ten months in the year.

Estimated volume and horse-power: Rock river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.									
Luverne	450	0.010	5	6	0.045	20	23	0.065	30	34
Rock Rapids	800	0.010	8	9	0.045	35	40	0.065	50	57
Mouth of river	1,660	0.015	25	29	0.045	75	85	0.065	110	125

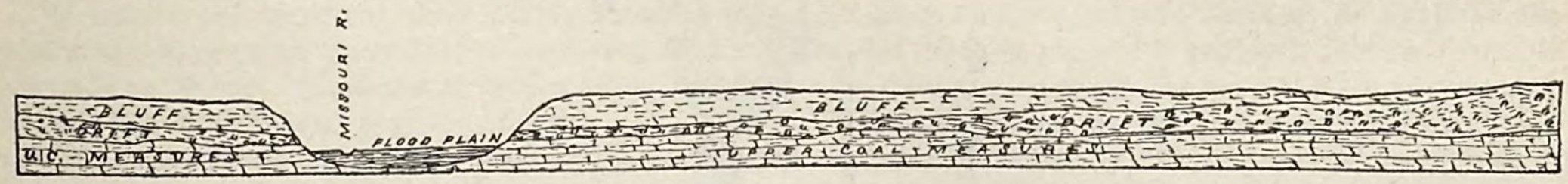
Summary of power used on rivers of southeastern Dakota.

Stream.	Tributary to what.	State or territory.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Dakota	Missouri	Dakota	Yankton	Flour and grist	1	6½	36
Do	do	do	Hutchinson	do	1	8	42
Do	do	do	Armstrong	do	2	14	60
Do	do	do	Hanson	do	1	10	50
Do	do	do	Stutsman	do	1	9	40
Total					6	47½	228
Vermillion	do	do	Clay	do	2	15	81
Do	do	do	Turner	do	3	20	52
Total					5	35	133
Big Sioux	do	Iowa	Plymouth	do	1	5	40
Do	do	do	Lyon	do	1	10	60
Do	do	Dakota	Union	do	2	12	57
Do	do	do	Lincoln	do	2	16	70
Do	do	do	Minnehaha	do	*4	42½	178
Do	do	do	Moody	do	1	10	45
Total					11	95½	450
Split Rock	Big Sioux	do	Minnehaha	do	1	23	50
Rock	do	Iowa	Sioux	do	1	10	50
Do	do	do	Lyon	do	1	14	60
Do	do	Minnesota	Rock	do	2	17	63
Total					4	41	173

* Not including power of Sioux Falls Water-Power Company, not yet in use.

TRIBUTARIES OF THE MISSOURI RIVER IN WESTERN IOWA.

In this class are comprised those rivers which the Missouri receives from the east, below the Big Sioux, extending to and including the Nishnabatona. The other principal streams thus embraced are the Floyd, Little Sioux, Soldier, and Boyer. The feature to which I wish especially to call attention is the geology of the region drained by these rivers. It is underlaid directly by only two formations—the Cretaceous and the Upper Coal Measures. Near the mouth of the Floyd, on the lower Boyer, and at points on the East and West Nishnabatona, their strata are slightly exposed, but in general they are concealed beneath the overlying Drift and Loess. The Drift is 150 to 200 feet thick along the ridge which divides the drainage basins of these streams from the basin of the Des Moines, and maintains a good thickness in northwestern Iowa. The Loess is thinnest on this ridge, but grows deeper as the Missouri river is approached, and in Fremont county, in southwestern Iowa, attains a depth of 200 feet.



SKETCH SHOWING RELATION OF RIVER VALLEY TO ADJOINING DEPOSITS (*a*).

The Loess, or Bluff deposit, as it is also called, is very pervious to water, and would probably have the same effect as sand in maintaining a uniform and large flow in the streams, if these had cut their way sufficiently deep to reach an impervious stratum which should shed the water into them. But in most cases they have not done this, and, consequently, much of the rainfall probably sinks to greater depths, runs along upon and through the underlying formations, and is lost to these streams. Dr. Charles A. White says of this deposit (*a*):

> Water passes through the material of the Bluff deposit as effectually as through ordinary sand, but not so quickly. That it is very pervious to water may be readily seen by observing the line of springs that issue at its base near the foot of the bluffs, and nowhere above that line. That it is so pervious also appears from the fact that wells dug in it, so far as has yet been ascertained, have never afforded a supply of water until the base, or very near the base of the deposit was reached. It will thus be seen that this strange deposit, although it is compact, is very porous, so that the water which falls upon its surface never collects there in ponds, nor does it accumulate within its mass, as it is known to do upon the surface of and within the Drift and stratified formations.

As defined by Dr. White, the eastern limit of this deposit in Iowa has the following course: Beginning with the southeast corner of Fremont county, it follows up the eastern water-shed of the East Nishnabatona to the southern boundary of Cass county; thence to the center of Audubon county; thence to Tip-Top station, on the Chicago and Northwestern railway; thence by a broad curve westward to the northwestern part of Plymouth county.

(*a*) *Geology of Iowa.*

THE FLOYD RIVER.

This is a small stream heading in Sioux and O'Brien counties, in northwestern Iowa. It runs southwesterly, and joins the Missouri at Sioux City. From the source of Willow creek its length by general course is about 70 miles. The area drained comprises 1,014 square miles, and consists of rolling prairie. The river runs through level bottom-land bordered by low hills; the bed and banks are generally of loam, and 5 to 10 feet in height. The current is sluggish in the lower river, but more rapid toward Le Mars. In the latter section the average width is 20 to 30 feet, increasing to 75 or 100 feet for the 10 miles above the mouth. In an ordinary stage, where running freely with straight course, the water is 1 to 2 feet deep. The banks are not often overflowed extensively, but the river has been known to spread out half a mile wide at Le Mars. Near the mouth the ordinary June rise is but a few feet, but in 1867 there was a rise of 22½ feet, said to be the greatest on record.

The river has good railroad facilities, and is closely followed by the Chicago, Saint Paul, Minneapolis and Omaha railway, and by the Illinois Central between Le Mars and the mouth. Sioux City and Le Mars are the principal towns. The first power met in ascending the river is at Sioux City, but a short distance from the mouth, and is used by a flouring-mill having three runs of stone, a brush dam, and 6 to 7 feet head. The pond is 2½ miles long and 75 feet wide. There are small mills, of one or two runs each, at James and at Merrill, and one of four runs at Le Mars. The dam at the latter point sets back the river for 2 miles, in which distance it has an average width of 40 feet, and creates a head of 10 feet. The mill is able to run at full capacity by water-power eight months in the year, but a 30 horse-power steam-engine is used the rest of the time.

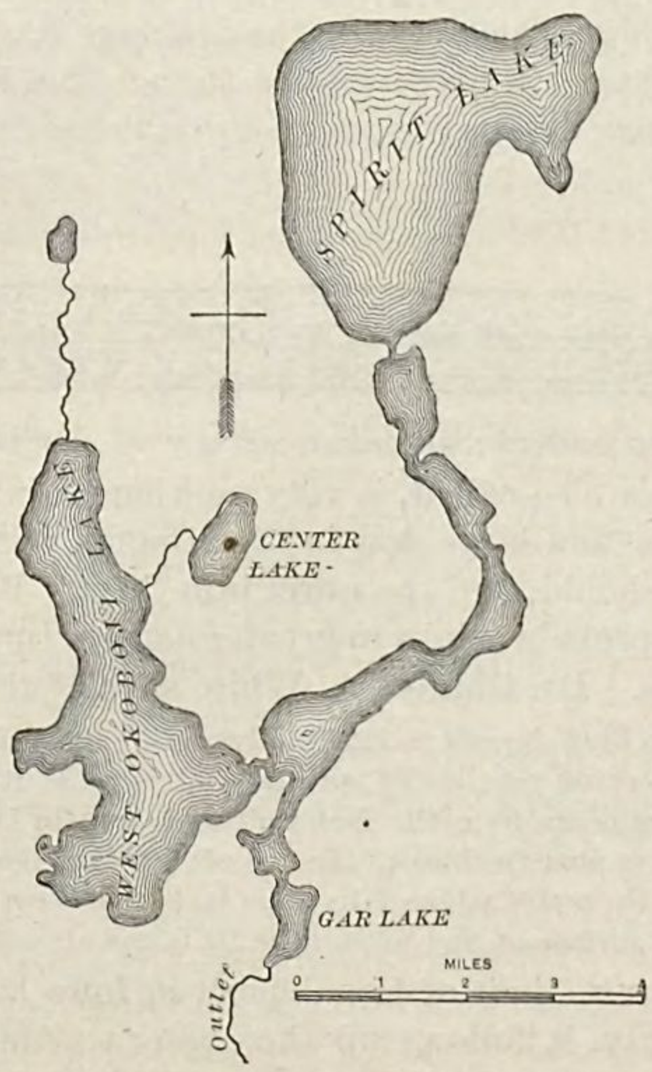
Elevations on Floyd river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Marshall†	1,165.0	57.5	17	3.38
Near mouth‡	1,107.5			

* Map measurement.
† Water surface at Illinois Central railroad crossing.
‡ Water surface at Sioux City and Pacific railroad crossing.

THE LITTLE SIOUX RIVER.

This important milling stream rises in southwestern Minnesota, but a short distance above the boundary between that state and Iowa; entering the latter state it takes a southwesterly course to the Missouri river, which



LAKES NEAR HEADWATERS OF LITTLE SIOUX RIVER.

it reaches some 40 miles to the northward from Omaha. Near its head it receives the waters of Spirit and Okoboji lakes. Spirit lake, the more northerly of the two, lies just south of the state line, and bordering upon it; it is quite regular in shape, and has a surface of 9 square miles. The dividing ridge between Spirit and Okoboji lakes is about 80 feet high, and through this runs the channel which connects the two. Okoboji lake is 2½ to 4 feet lower than its companion, and has approximately the same area; it has a horseshoe shape, with a length, following the bends, of 15 miles. Narrow in the eastern portion, it expands toward the west into what was called by the Indians *Minnetonka*, Sioux for "Great Water". This part of the lake is said to attain a depth of nearly 100 feet at one point. Both the lakes which have been described have gravelly beds, very clear waters, and, with their thickly wooded shores, present a charming appearance.

From its source to the southern part of Cherokee county the course of the Little Sioux lies upon the Drift. In this distance the valley is a quarter to a half mile wide, the bed is gravelly and sandy, the banks are gravelly and rather low, and frequently only 4 to 6 feet high. At Peterson the river is described by Dr. White as passing through a gorge not more than a quarter of a mile wide, in which it lies nearly 200 feet below the surrounding country; yet throughout this depth there is displayed nothing but Drift. Passing down through Cherokee county the region of the Loess is reached, and the valley widens out. The banks are 15 to 20 feet high, and both they and the bed are composed of soft mud. The bottom-land is bordered by bluffs, which continue for 8 miles into Monona county; but below that locality the valley is merged into that of the Missouri. About midway in Monona county the Little Sioux is joined by the West fork and Maple river. At some period in the past these were independent streams, each emptying by itself into the Missouri, which then ran close to the Iowa bluffs; but the Missouri now lies 8 or 10 miles farther west, and the Little Sioux, joined by its two tributaries, runs for a while in the old channel of the Missouri, and then crosses the flood-plain to its present course.

The basin of the Little Sioux lies in the least thickly settled portion of Iowa, and at present the greater part of its course is not adjacent to any railroad. It is crossed, however, at right angles at Cherokee and Spencer, points in its middle and upper course, respectively; and is also crossed by the Sioux City and Pacific line at its mouth. Cherokee, population, 1,500, and Spencer, 800, are the principal towns on its course.

Elevations on Little Sioux river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Feet per mile.*
Cherokee †	1,143	101	79	1.28
Near mouth ‡	1,042			

* Map measurement.
† (565 feet above low water at Dubuque) Illinois Central railroad levels, water surface.
‡ (460 feet above lake Michigan) Sioux City and Pacific railroad levels, water surface.

The surface drained by the Little Sioux has an area of 4,233 square miles. It is a rolling prairie, fertile, and well adapted to corn, wheat, and other grains. Timber is confined to fringes along the streams; a considerable amount is found in the vicinity of Spirit lake, and below that the course of the river is bordered by a moderate amount of cottonwood, oak, and basswood.

In an average stage the river has a current of perhaps 3 miles an hour below Cherokee; its depth in the same stage ranges from 3 to 5 feet between Peterson and the mouth, while the width gradually increases from 40 feet to 60 or 70 feet. Its course is very winding, and it runs back and forth across the bottom land, approaching first one line of bluffs and then the opposite. In its upper course the banks are not commonly submerged to a serious extent; as the mouth is approached, however, the stream becomes more sluggish, perhaps also more crooked, than above, and is subject to a freshet rise of 15 or 20 feet. It is not flashy, and is not much affected by ordinary storms; but in spring, when the snow is melting, and during the heavy summer rains, it is liable to overflow its banks, and in its lower course sometimes spreads out to a width of 2 or 3 miles.

Between Cherokee county and the mouth there is a large fall unimproved, but this portion of the river is neither considered valuable nor utilized, on account of its heavy rises, muddy bed and banks, and the consequent difficulty in maintaining dams. There are rapids in the Sioux just north of the Harrison county line, and there is one small mill, with 4 feet head, returned as using the river for power in that county; but with this exception there is said to be but one mill below Correctionville, and that is a small one at Smithland, having two or three runs and a brush dam. Above Smithland I learned of the following mills: Correctionville, one mill of two runs; 7½ miles below Cherokee, one mill of two runs; 6 miles below Cherokee, one mill of one run; Cherokee, one mill of four runs; Peterson, one mill of two runs; Sweet's mill, two runs; a small mill at Sioux Rapids; one of three runs at Spencer; one of four runs, and one of three runs at Okoboji outlet.

The river is at its lowest stage from December on through the winter, and runs highest usually in June. During high water the mills are troubled by the set-back and consequent loss of head. Their dams were described to me as being in many cases cheaply built of brush, and apt to be cut away, in part at least, by the river. They probably average 100 feet in length by 6 to 8 feet in height.

The power at Cherokee is occupied by a four-run flouring-mill, using about 75 horse-power, with 7 feet fall. There is sufficient water for running at full capacity nine months in the year, but the mill is shut down the remainder of the time. The dam was built in 1871, and is of crib-work, 130 feet long and 7 feet high. The pond is 2½ miles long and averages 100 feet in width and 4 feet in depth.

Of the two mills on the outlet of lake Okoboji the larger carries four runs of stone, and is operated by the Milford Water Power Improvement Company.

Of the tributaries of the Little Sioux, the West fork is not a mill stream; Maple river is in appearance about one-third the size of the main river, and has several flouring- and grist-mills.

THE SOLDIER RIVER.

Rising in Ida county, Iowa, this river runs southwesterly across portions of Crawford, Monona, and Harrison counties, and empties into the Missouri 13 miles south of the Little Sioux. It is 60 miles long by general course, and drains an area of 529 square miles, long and narrow in shape, and measuring only 12 or 14 miles across in the broadest part. There are no important towns on the stream, and it is not touched by any railroad except at its mouth. It is about two-thirds the size of the Boyer river to the south, and has a moderate current, with a bed mainly composed of mud, but showing gravel in some places. The banks are of loam, 10 to 15 feet high, and are overflowed every few years, an extreme freshet rise of 25 feet having been noted. The river might be used for a small power once in a few miles, but at present there are only two mills on its course; these carry about two runs of stone each, and are able to run at full capacity nine months in the year. During the remainder of the time they are troubled by either a low stage or by backwater.

THE BOYER RIVER.

The Boyer river rises in Sac county, and, following the southwesterly direction common to the streams of this section, empties into the Missouri 10 or 12 miles north of Council Bluffs. The area drained is 80 to 90 miles long, 12 to 15 miles wide, and contains 1,123 square miles. From its extreme source the river has a length of about 85 miles by general course. The Chicago and Northwestern railway follows the stream closely below Denison, and along its course are a number of thriving towns, of which the most important are Denison, population about 1,400; Logan, 600; and Missouri Valley, 1,200. Toward the headwaters the country is a flat prairie. The valley of the stream averages about 1½ miles in width, though in places it expands to 3 miles, and is bordered by bluffs 40 to 100 feet high. No lakes are drained, and the surface of the country is not suited to storage reservoirs.

In an ordinary stage the Boyer is 50 to 60 feet wide and 2 feet deep, with a moderate current. The bed is mostly mud, but occasionally gravel. At only one point does rock appear, and that is in the vicinity of Logan; here are a few exposures of limestone belonging to the Upper Coal Measures, their only occurrences in Harrison county, and the most northerly of the kind in Iowa. The lowest stratum of this exposure is 3 to 4 feet thick, and consists of a compact, light-gray limestone, with clay partings. It is well suited to building purposes, and at several points near Logan has been quarried and used. The river banks are of loam, and rise 10 to 15 feet above low water. Once in a few years the Boyer overflows its banks, and spreads out from bluff to bluff; the highest rise noted in the lower river was about 25 feet, or at least 10 feet above the general level of the banks.

The use of water-power is confined to flouring-mills, which, I was informed, are located as follows, ascending the stream: Loveland, one mill of four runs, with timber dam; Logan, one mill of two runs; Woodbine, one mill of two runs, with brush dam; Dunlap, one mill of three runs. There are also mills at Dow City, Denison, and Mason's Grove. These mills have, in general, a fall of 7 or 8 feet, and surplus power during a portion of the year; for two or three weeks they are troubled by backwater.

At Logan, power is used by a flouring-mill of two runs, with two wheels under a head of 8 feet. The dam was built in 1856, and is of stone, 60 feet long, 8 feet high, and 8 feet wide at the top; it rests upon a limestone ledge, and abuts upon rock at one end and upon a masonry wall at the other; it has no apron. The supply of water is sufficient for running at full capacity eight months in the year, and two-thirds capacity the rest of the time.

It is considered that the Boyer would furnish power for four or five runs of stone during the greater part of the year; less than half the fall of the stream below Denison is now employed, and numerous sites might be found both below and above that point, where a head of 7 or 8 feet could be secured.

Elevations on Boyer river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Denison †	1,162	72	22	3.27
Near Dunlap †	1,090	76	37	2.05
Mouth of river ‡	1,014			

* Map measurement. † Water surface by Chicago and Northwestern railway levels. ‡ Estimated.

THE MOSQUITO RIVER AND KEG CREEK.

These are the next tributaries of the Missouri below the Boyer river. Mosquito river is 60 miles long by general course, and toward the mouth is 20 or 30 feet wide in an ordinary stage and 3 feet deep. The bed is muddy, the banks are of loam, and 10 feet in height. The current is moderate in the upper course, but sluggish as the Missouri is approached. The banks are occasionally overflowed, and in the dry season the stream runs very low. It is used for power by two flouring- and grist-mills, but has not much value. Keg creek is a small stream of no special importance, but has three flouring-mills.

THE NISHNABATONA RIVER.

This river is formed by two forks, the East and the West, which rise 60 to 70 miles northeast of Council Bluffs, and, flowing southerly, unite in Fremont county. The main river is only about 30 miles long by straight course. It formerly emptied into the Missouri near Hamburgh, in the southwestern corner of Iowa, but work done ten or twelve years ago, in connection with the Kansas City, Saint Joseph and Council Bluffs railroad, changed its course, so that it now enters the Missouri in Atchison county, Missouri, 20 miles to the southeast of its old mouth.

The entire area drained by the Nishnabatona is 3,100 square miles, of which 1,146 belongs to the East Fork and 1,678 to the West Fork. The country is rolling and very fertile, corn, wheat, and other grains being the chief productions. Limestone is found, and good brick clay. Borings have been made for coal, but it seems to lie too deep to be successfully worked. The old growth of timber has been mostly cut away, but there is an abundance of young growth, mostly soft maple and elm. The main river is 150 feet wide in an ordinary stage. There are no mills upon its course, and it is not probably of much value for water-power, on account of slight fall and backwater from the Missouri. It strikes into the broad bottom of the latter stream at Hamburgh, a place of about 2,000 inhabitants.

The East Nishnabatona is about 100 miles long by general course. Its immediate valley is 1 to 3 miles in width, and shows a gradual rise to the bluffs, which reach elevations of 50 to 200 feet above the river. A branch of the Chicago, Burlington and Quincy railroad follows the stream from its mouth through the greater part of its course, and it is also crossed by railroads at three points in directions at right angles to its own. Red Oak and Atlantic are the principal towns on the river, the former with a population of about 3,800, and the latter with 3,700. The width of the stream in an ordinary low stage increases from 75 feet at Red Oak to 100 feet at the mouth, and the depth from 3 feet to 5 or 6 feet. The only mill in Fremont county on the lower river is a mile and a half north of Farragut. It carries three runs of stone, and has a frame dam resting on piles. In this section of the river the bed is muddy, the banks are of loam, and 5 to 10 feet high. There is a moderate fall, and the stream has a good current; it is subject to an extreme freshet rise of about 8 feet, and once in every few years overflows its banks and spreads out in places from bluff to bluff.

Ascending the stream the next power is in use at Heiner's mill, 1 mile south of Red Oak. The dam was built in 1867, and is 90 feet long by 7 feet in height. It rests upon a foundation of gravel, clay, and sand, and abuts upon a crib-work at one end and upon a mass of brush and earth at the other. The structure itself is of brush, and gives a head of 7 feet. The pond is claimed to extend 7 miles up the river. Heiner's mill has three runs of stone, and wheels of 60 horse-power. It can commonly be run at full capacity throughout the year, and the proprietor considers his privilege good, in general, for five runs of stone at the lowest stage of river.

The East Nishnabatona has in this section a muddy bed, with occasional rock ledges. The banks are of loam, and 10 to 15 feet high. Every few years the bottoms are extensively overflowed, and nearly every year in low places. The extreme freshet rise is about 18 feet. There are mills at points 2 miles and 9 miles above Red Oak, and some others above, but only a small portion of the fall of the stream has been developed.

Elevations on East Nishnabatona river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Atlantic †	1,128			
		124	37	3.35
Red Oak ‡	1,004			
		43	22	1.95
Near Shenandoah §	961			
		63	61	1.03
Near mouth main river ‖	898			

* Map measurement.
† Chicago, Rock Island and Pacific railway crossing.
‡ Chicago, Burlington and Quincy railroad crossing.
§ Water surface at Wabash, Saint Louis, and Pacific railway crossing.
‖ Water surface at Kansas City, Saint Joseph and Council Bluffs railway crossing.

The West Nishnabatona is very similar to the East Fork. The bottom-land bordering it averages 2 miles in width, and is in places 3½ miles wide. To the east of Council Bluffs the river averages 75 feet across at an ordinary

stage, with a depth of 5 to 8 feet. The bed is mostly mud, with occasionally gravel and rock; the banks are of loam, and 15 to 20 feet high. This stream has a moderately swift current, and sometimes overflows its banks during severe freshets. Both the West and the East Forks are muddy streams, and especially so after heavy rains. They have a tolerably steady flow, and are not very rapid in rise and fall. They are very crooked and sluggish in their lower courses. High water occurs from April to June, and is followed by a decreasing volume, with low water in August and September. There are only 3 mills on the West Fork—one in Shelby county, and two in Pottawattamie county. A still less proportion of the fall of this stream has been developed than of the East Fork, the reasons for the small use of power in this section being claimed to be a lack of demand for mills, and a scarcity of capital. The West Nishnabatona has good railroad facilities, and is followed closely by a branch of the Chicago, Burlington and Quincy railroad. The larger towns adjacent to its course are Sidney, population about 900; Avoca, 1,600; and Harlan, 1,300.

Elevations on West Nishnabatona river.

Locality.	Elevation above sea.	Fall between points.	Distance between points. *	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Avoca †	1,103	119	39	3.05
Near Lawrence ‡	984			
Near mouth of main river §	898	86	66	1.30

* Map measurement.
† Chicago, Rock Island and Pacific railway crossing.
‡ Water surface at Wabash, Saint Louis and Pacific railway crossing.
§ Water surface at Kansas City, Saint Joseph and Council Bluffs railroad crossing.

Walnut river and Silver creek are the only important tributaries of the West Nishnabatona, and are both employed for power by a few flouring- and grist-mills. Walnut river joins the main stream from the east about 7 miles above its mouth. It has a muddy bed, and banks of loam, rather low in places. In an ordinary stage this stream is 50 feet wide, 5 feet deep, has a moderately swift current, and is of fair value for small powers.

The average rainfall over that portion of western Iowa which has been considered is not far from 8 inches in spring, 14 in summer, 8 in autumn, and 3 in winter, making 33 inches for the year. It is rather less, however, in the northern part of the district. Having been unable to find any records whatever of gaugings of the streams, I have prepared rough estimates of their volumes, which are given in the accompanying table, and may be of some service in showing their capabilities for power.

Estimated volume and horse-power of the Western Iowa tributaries of the Missouri river.

Stream.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
Floyd:	*Sq. miles.*									
At Le Mars	481	.....	.....	.....	0.040	20	23	0.070	30	34
At mouth	1,014	0.020	20	23	0.040	40	46	0.070	70	80
Little Sioux:										
At Sioux Rapids	1,362	0.030	40	46	0.040	50	57	0.070	95	108
At Cherokee	2,075	0.030	60	68	0.040	80	91	0.070	145	165
At Correctionville	2,445	0.030	70	80	0.040	100	114	0.070	170	194
At mouth	4,233	0.030	130	148	0.040	170	194	0.070	300	342
West Fork	625	0.020	10	11	0.040	25	28	0.070	40	46
Maple river	819	0.025	20	23	0.040	30	34	0.070	60	68
Soldier:										
At Hall creek	382	.....	.....	.....	0.050	20	23	0.080	30	34
At mouth	529	0.020	10	11	0.050	30	34	0.080	40	46
Boyer:										
At Crawford	546	0.020	10	11	0.040	20	23	0.060	30	34
At Logan	834	0.025	20	23	0.040	30	34	0.060	50	57
At mouth	1,123	0.030	30	34	0.040	45	51	0.060	70	80
Mosquito river	285	.....	.....	.....	.....	.....	.....	0.060	20	23
Keg creek	324	.....	.....	.....	.....	.....	.....	0.000	20	23
Nishnabatona:										
At Riverton	2,824	0.040	110	125	0.060	170	194	0.080	230	262
At mouth	3,100	0.040	120	137	0.060	190	217	0.080	250	285
East Fork:										
At Red Oak	409	0.050	20	23	0.080	30	34	0.100	40	46
At mouth	1,146	0.050	60	68	0.080	90	103	0.100	115	130

Estimated volume and horse-power of the Western Iowa tributaries of the Missouri river—Continued.

Stream.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
West Fork:	*Sq. miles.*									
At Nishna	605	0.025	15	17	0.050	30	34	0.070	40	46
At Hastings	984	0.030	30	34	0.050	50	57	0.070	70	80
At mouth	1,678	0.030	50	57	0.050	80	91	0.070	120	137
Walnut river	245	.....	.....	.....	0.040	10	11	0.080	20	23
Silver creek	259	.....	.....	.....	0.040	10	11	0.080	20	23

Power utilized on the Western Iowa tributaries of the Missouri river.

Stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Floyd	Missouri	Iowa	Woodbury	Flour and grist	1	10	50
Do	do	do	Plymouth	do	1	12	11
Little Sioux	do	do	Harrison	Flour, grist, and saw	1	4	57
Do	do	do	Woodbury	do	3	22	162
Do	do	do	Cherokee	Flour and grist	3	19	144
Do	do	do	Buena Vista	do	2	17	106
Do	do	do	Clay	do	2	16	134
Maple	Little Sioux	do	Monona	do	3	22	120
Do	do	do	Ida	do	2	18	62
Small streams	do	do	Woodbury	do	1	35	40
Do	do	do	do	Carpentering	1	22	5
Do	do	do	Cherokee	Flour and grist	1	8	15
Do	do	do	Dickinson	do	2	30½	62
Soldier	Missouri	do	Harrison	do	2	13	57
Boyer	do	do	do	do	2	20	95
Do	do	do	Crawford	do	3	25	84
Do	do	do	Sac	do	2	18½	25
Small streams	Boyer	do	Harrison	do	1	8	18
Do	do	do	Crawford	do	1	8	20
Pigeon	Missouri	do	Pottawattamie	do	1	11	28
Mosquito	do	do	do	do	2	18	90
Keg	do	do	Mills	do	3	33	108
Small stream	do	do	Fremont	do	1	20	8
East Nishnabatona	Nishnabatona	do	Montgomery	do	3	22	118
Do	do	do	Cass	do	2	18	76
Do	do	do	Audubon	do	2	18½	40
Small streams	East Nishnabatona	do	Cass	do	2	19	86
West Nishnabatona	Nishnabatona	do	Pottawattamie	do	2	14½	60
Do	do	do	Shelby	do	1	8	45
Walnut	West Nishnabatona	do	Fremont	do	4	43	154
Do	do	do	Montgomery	do	1	10	20
Silver	do	do	Mills	do	3	23	95
High	Nishnabatona	Missouri	Atchison	do	1	8	26
Rock	do	do	do	do	2	35	44
SUMMARY.							
Floyd	Missouri	Iowa			2	22	61
Little Sioux	do	do			11	78	603
Tributaries	Little Sioux	do			10	135½	304
Soldier	Missouri	do			2	13	57
Boyer	do	do			7	63½	204
Tributaries	Boyer	do			2	16	38
East Nishnabatona	Nishnabatona	do			7	58½	234
Tributaries	East Nishnabatona	do			2	19	86
West Nishnabatona	Nishnabatona	do			3	22½	105
Tributaries	West Nishnabatona	do			8	76	269
Small streams	Nishnabatona	Missouri			3	43	70
Do	Missouri	Iowa			7	82	234
Total					64	629	2,265

TRIBUTARIES OF THE MISSOURI RIVER IN NORTHERN MISSOURI.

The streams which I shall describe under this head extend from the Nishnabatona on the west, to the Chariton on the east, and include the latter; below the Chariton the Missouri receives no tributaries of any importance from the north. They rise in southern Iowa and run southerly into Missouri, the principal portions of their courses lying in the latter state. The section of country which they drain is rich farming land, contains beds of coal and limestone, and has a fair amount of timber, covering, perhaps, one-fourth of the surface, which is everywhere rolling. Corn and wheat are largely raised, and in some counties fine crops of tobacco are produced. The means of communication are good; numerous lines of railway run north and south, east and west. To the east and south are the Mississippi and Missouri rivers, navigable, and constantly drawing more and more attention to their improvement.

The rivers to be discussed are not navigable, and in only one or two cases are they much used for rafting. They are employed to a considerable extent for power by flouring- and grist-mills, and answer moderately well for such use. They are not, however, suited to purposes of general manufacturing of much importance. They are subject to heavy overflows in the spring or early summer, while in the late summer or fall they run extremely low. Through the more important portions of their courses they have but a slight fall and are winding and sluggish. The beds and banks are usually muddy, and the common tendency toward a low bank on one side, while the opposite one is of normal height, renders it often difficult to find a suitable location for a dam, or to prevent overflowing the banks by backwater from the mill-ponds.

THE BIG TARKIO RIVER.

This stream heads in Page and Montgomery counties, in southwestern Iowa, and, flowing southerly, passes through Atchison and Holt counties, Missouri, and joins the Missouri river. It drains 543 square miles, and has a length, by general course, of 75 or 80 miles. For a considerable distance above the mouth it runs through the Missouri river bottom, and has no separate valley; but farther up stream it is bordered by bottom-land which forms its own distinct valley, 1 mile to 1½ miles in width, and bounded by bluffs of moderate height. In ordinary low water the Tarkio is about 125 feet wide in its lower course, and 2 to 3 feet deep. The banks are of loam, 10 to 12 feet high. It is a muddy stream, with a moderate current when low, but flows rapidly in high water. It gets very low in summer, and on account of its small volume and slight declivity has not much value for power. Rising more rapidly after heavy rains than the Nodaway, which lies next east, it has a range of perhaps 10 feet between low and high water; occasionally it rises 2 or 3 feet above its banks and submerges the bottom-land. The number of mills employing this stream for power and its estimated volume will be given in subsequent tables.

Elevations on Big Tarkio river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Snow Hill, Page county, Iowa †.	979	109	35	3.12
Craig, Holt county, Missouri ‡.....	870			

* Map measurement.
† Water surface at Wabash, Saint Louis and Pacific railway crossing.
‡ Water surface at Kansas City, Saint Joseph and Council Bluffs railroad crossing.

THE NODAWAY RIVER.

The Nodaway is formed by small streams having their sources in Cass and Adair counties, in southwestern Iowa; it runs southerly and empties into the Missouri 10 miles north of Saint Joseph. Its basin is quite narrow in Missouri, but expands somewhat toward the headwaters in Iowa, and has an area of 1,886 square miles. From the head of the Middle Fork to the mouth of the main stream the distance by general course is 120 miles. The valley of the stream varies from a quarter of a mile to 3 miles in width, and is bordered by bluffs 100 to 200 feet high. Corn is the chief production of the bottom-land, and corn and wheat of the upland. Considerable timber, mostly oak, is found for the first 10 or 12 miles above the mouth, but not a great deal beyond. Limestone, well suited to building, occurs along the course of the river, also an inferior quality of brick clay; no coal is obtained near the mouth, and but little above.

The river bed is fine mud, and the banks are of loam, 10 to 12 feet high; rock is seldom found, except on one side, where a bluff has been cut into by the current. There is no navigation, no rafting, and the only use, in fact, to which the stream is put is to furnish power to flouring- and grist-mills, of which there are quite a large number, leaving but a small amount of fall unutilized below Villisca. It is said that the mills on the lower river can

commonly run at full capacity throughout the year, though in the dry season the river is very low and they do not probably have much surplus power. The lowest mill has backwater from the Missouri when the latter is high. The streams of northwestern Missouri are claimed to have much deteriorated since the settlement of the country; they formerly ran with full banks, but the cutting away of the timber and the cultivation of the soil have sensibly lessened their low-water volumes; springs have diminished and the soil has washed in and filled up their beds.

Elevations on Nodaway river.

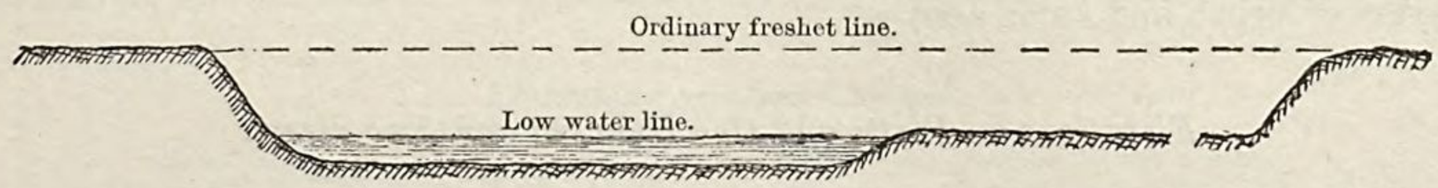
Locality.	Elevation above sea.	Fall between. points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Villisca †	1,001	87	32	2.72
Near Claremont ‡	914			
Near mouth §	841	73	59	1.24

* Map measurement. † Chicago, Burlington and Quincy railroad crossing.
‡ Water surface at Wabash, Saint Louis and Pacific railway crossing.
§ Water surface at Kansas City, Saint Joseph and Council Bluffs railway crossing.

THE PLATTE RIVER OF MISSOURI.

Formed by small streams rising in Union and Adams counties, in southwestern Iowa, the Platte enters Nodaway county, Missouri, and keeping a southerly direction empties into the Missouri river in southern Platte county. From its extreme source it has a length, by general course, of 140 miles, and drains an area of 2,487 square miles. Its principal tributary is One Hundred and Two river, which joins it 6 miles east of Saint Joseph. This section has fine railroad facilities; several important lines cross the river at various points, and a branch of the Chicago, Burlington and Quincy railroad follows a considerable portion of the course of One Hundred and Two river. The more important towns are, on Platte river, Platte City, population about 700; on One Hundred and Two river, Savannah, population, 1,200; Maryville, 3,500; Hopkins, 900; and Bedford, 1,800.

The valley of the Platte is very fertile, corn being the chief production of the bottom-land, and corn and wheat of the upland. There was formerly a heavy growth of timber, comprising white oak, burr oak, ash, hickory, maple, and locust, but it has been largely cut away within the past few years on the lower river; in Andrew county considerable amounts of oak, elm, and hickory still remain. In Platte county, near the mouth, inferior qualities of brick clay and limestone for building are found, and here and there a little coal. The river is muddy at nearly all times, and in high water carries much drift; a good business is done in rafting logs and railroad ties down to Platte City, and small craft are able to ascend the stream to that point. The lower valley averages 2 miles in width, and is flanked by bluffs 200 feet high. The stream itself is, in Andrew county, 75 to 90 feet in width, in an ordinary stage, and 3½ to 4 feet deep; at Platte City it runs 150 feet wide in ordinary low water, and 3 to 5 feet deep, while in mean high water the corresponding dimensions are 300 feet and 15 feet. The banks are of loam, and average 15 feet in height throughout the lower portion of the river. Although this is the normal height, and usually reached by one bank or the other, the opposite one is almost invariably low, from the action of the river in cutting away its banks, shifting its channel, and building bars, and a cross-section is produced as illustrated in the



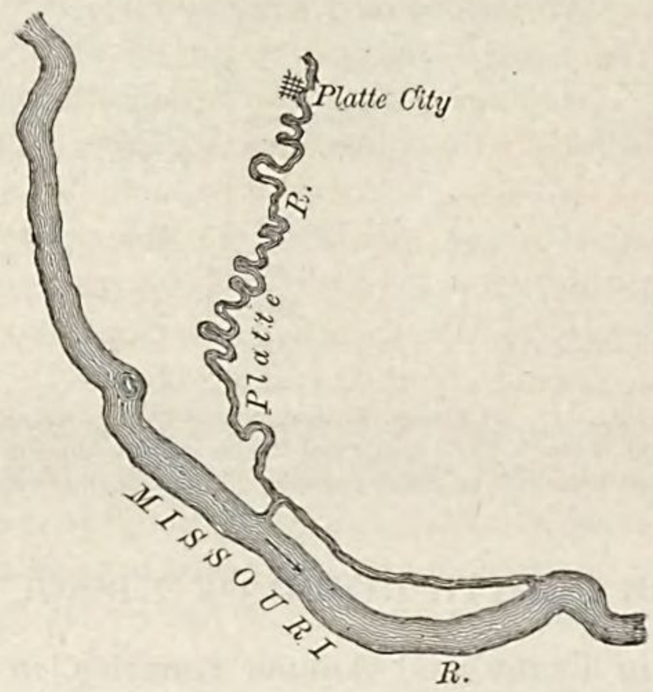
CROSS-SECTION OF RIVER AND BANKS.

cut. The bed is muddy, as a rule, but exhibits occasional riffles over ledges of limestone rock. The river is very crooked, and in low water has a sluggish current, which becomes rapid as a high stage is again approached.

The Platte never runs dry, though it reaches a very low stage in September and October. It is subject to very sudden rise and fall after heavy storms, and sometims rises several feet in a few hours. High water occurs in May and June, and sometimes also in the fall. The lower river is liable to an extreme freshet rise of about 25 feet, and once in five or ten years overflows its banks, spreading out in places from bluff to bluff, and running from a mile to a mile and a half in width.

The lowest mill on the river is at Platte City, 20 miles northwest of Kansas City. The dam was built in 1874, and is 100 feet in length by 7 feet in height. It is an open framed structure resting upon a bed of limestone, to which it is bolted down. It abuts at one end upon a log crib-work filled with stone, and at the other end upon the timber wall of the race; it is not provided with an apron. The pond extends 3 miles up the river. The mill carries three runs of stone, and has wheels of about 70 horse-power, working under a head of 7 feet. There is sufficient

water for running at full capacity eight months in the year, but the mill is stopped for two months by backwater, and for another period of two months can only run at about one-third capacity on account of low water. The old mouth of the Platte was farther down the Missouri than the present one, but the latter stream cut into its course and gave it a new outlet. Since that occurrence there has been 5 feet more dead-water at Platte City than before, and the mill at that point has suffered accordingly.



SKETCH SHOWING CUT-OFF.

There is only one other improved power on this river in Platte county, and that is occupied by the Union Mills, carrying two or three runs and having a frame dam filled with stone, resting upon a rock ledge. Farther up stream there are mills at frequent intervals, but I did not learn their exact locations; they will be given by counties in a subsequent table. The dams are said to be usually brush or framed structures, and to give a fall, in general, of about 8 feet. A large proportion of the fall of the Platte and One Hundred and Two rivers remains unimproved, mainly from a lack of demand for power.

One Hundred and Two river runs parallel to the main stream, and much of the way is distant but a few miles from it to the west. In an ordinary stage of water it is 80 to 90 feet wide in Andrew county, and 3 or 4 feet deep. It is bordered by considerable timber, but is not used for rafting. The bed is generally mud, but once in 3 miles, on an average, there is a riffle with rock bottom. The banks are of loam, and are about 15 feet in height above low water. The volume holds out better in the dry season than in the case of the main stream, still the river runs very low for six weeks or two months in late summer and fall. There is only a moderate current during a low stage, but in high water the stream is quite swift; once in several years it overflows the banks and runs 18 feet deep. It is considered to have fair value for power, and mills are located at the following points as you ascend the river: Avenue City, one mill of three runs; Phillips' mill, east of Savannah, two runs; Rosendale, one mill of three runs; Barnard, one mill of three runs; near Arkoe, one mill of two runs; Bedford, Iowa, one mill. There are probably one or two others not included in this list. The dams are said to be usually brush or framed structures, giving a fall of about 8 feet. The brush dams are built in the common manner—a layer of trees on the river bed, with successive layers of brush and stone above.

Elevations on Platte and One Hundred and Two rivers.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
Platte river.	*Feet.*	*Feet.*	*Miles.*	*Ft. per mile.*
Near Conception†	1,076	269	62	4.34
Near Frazier†	807	52	57	0.91
Near mouth‡	755			
One Hundred and Two river.				
Near Hopkins‡	1,048	145	35	4.14
Near Rosendale‡	903	148	94	1.57
Near mouth Platte‡	755			

* Map measurement.
† Water surface at Wabash, Saint Louis and Pacific railway crossing.
‡ Water surface at Kansas City, Saint Joseph and Council Bluffs railroad crossing.

THE GRAND RIVER.

The Grand river is formed by a number of small streams which rise in the southwestern counties of Iowa, 30 to 50 miles above the state line. Flowing southerly into Missouri, they finally combine into two principal forks—the East and the West—which themselves unite near Chillicothe, in Livingston county; the main river then takes a southeasterly course for 35 miles to the Missouri river, which it joins at Brunswick, on the western border of Chariton county. From the source of the West Fork, in Union county, Iowa, to the mouth of the main stream, the distance by general course is 140 miles. The total area drained by Grand river is 7,932 square miles. The surface is a rolling prairie, well timbered along the streams with cottonwood, elm, hickory, and walnut. Limestone exists plentifully in the bluffs, and sandstone crops out in at least one locality. The country is quite well settled, and has good railroad communications. The Wabash, Saint Louis and Pacific railway strikes the West Fork in Gentry county, and continues down the valley and to the mouth of the main river; some of the other tributaries are similarly followed by different lines. The more important places on the streams are: on the Grand, Brunswick, population, 1,800, and Chillicothe, 4,100; on the West Fork, Gallatin, 1,100, and Albany, 1,000; on the East Fork, Trenton, 3,300; and Princeton, 1,200; on Locust river, Linneus, 900.

Both the East and the West Forks are in their lower courses bordered by rich farming land, but the "first bottom" is injured for agricultural purposes by its liability to overflows, which occur nearly every year and sometimes several times in a single year. The valley of the East Fork is rather broader than that of the other, and averages 1 to 2 miles in width. Both rivers have beds principally composed of mud, sand, and gravel, and contain very few rock ledges. Their banks are of alluvial soil, and average 20 feet in height above low water, being usually high on one side and low on the opposite. The country drained is very deficient in springs, and the streams have, therefore, to depend chiefly upon surface drainage to maintain their flow. The East and West Forks are very sluggish in their lower portions, and very few riffles are to be seen; levels have been run along the former near Chillicothe, revealing a fall of about 6 inches to the mile. This stream averages a little more than 100 feet in width near its mouth, and for four or five months in the year is 2 to 3 feet deep on the riffles; it has a very crooked course. The West Fork is straighter and also somewhat wider, averaging 150 feet across.

Ascending from the Missouri, the first power in use is at Graham's mill, on the East Fork. The dam is in part framed and in part built of logs, and is filled in with loose stone; it rests upon rock for a portion of the distance across the river, and has abutments of crib-work filled with stone. The length of the structure is 112 feet, its height 8 feet, and its cost was about $1,000. The river bed is protected from scour by an apron of hewn timber, extending under the entire dam and projecting 10 feet below it down stream. Graham's mill can be run at full capacity eight months in the year, but for two months it is stopped by backwater, sometimes for six weeks at a single stretch, and for an additional period of two months low water prevents running at more than about one-half capacity. Three runs of stone are carried, power being furnished by three water-wheels of 12 horse-power each.

There are no mills below Chillicothe, though there is said to be a fine unimproved site at Bedford, a little place some 25 miles above the mouth of the river, and beyond the reach of backwater from the Missouri. Above Chillicothe there are flouring- and grist-mills at frequent intervals on both forks, although a large part of the fall of each still remains undeveloped. The dams on these streams are usually brush or framed, rest upon mud or gravel beds, and yield heads of 7 or 8 feet. The brush dams are constructed of brush and saplings laid with the stream, cross-logs for binders, and stone filling; they stand well and give very good satisfaction. The mills on the East Fork are stated to have their principal trouble from backwater; those on the West Fork have less difficulty from that source, but are troubled to a greater extent by a scarcity of water in the dry season.

Elevations on Grand river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
West Fork and main river.	*Feet.*	*Feet.*	*Miles.*	*Ft. per mile.*
Near Gentryville †	816	136	76	1.79
Mouth Weldon river ‡	680			
Mouth Grand river †	635	45	52	0.87
East Fork.				
Four miles east of Afton, Iowa §	1,005	322	145	2.22
Near Chillicothe †	683			

* Map measurement.
† Water surface at Wabash, Saint Louis and Pacific railway crossing.
‡ Estimated.
§ (500 feet above low water at Burlington) Chicago, Burlington and Quincy railway levels.

THE CHARITON RIVER.

This stream has its sources in Clarke and Wayne counties, in southern Iowa, about 20 miles north of the Missouri boundary. Entering the latter state it runs southerly, and empties into the Missouri river at the southern extremity of Chariton county. It is 150 miles long by general course, and drains 2,900 square miles. It is crossed at frequent intervals by important east-and-west railway lines, and a division of the Wabash, Saint Louis and Pacific road follows up its eastern water-shed, distant most of the way less than 10 miles from the river. Chariton, near the headwaters, is the only important place directly upon the river; but below that point are Centerville, in Appanoose county, Iowa, having a population of 2,500, and distant 5 miles from the river to the west; Kirksville, Adair county, Missouri, 2,300 inhabitants, and lying 5 miles east of the river; Keytesville, 12 miles from the mouth, and distant but 1 mile from the river's course.

Elevations on Chariton river.

Locality.	Elevation above sea.	Fall between points.	Distance between points. *	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Chariton, Iowa †	1,030	281	105	2.68
West of Kirksville, Missouri ‡	749			
Near Keytesville ‡	627	122	81	1.51

* Map measurement.
† (525 feet above low water at Burlington) Chicago, Burlington and Quincy railroad levels.
‡ Water surface at Wabash, Saint Louis and Pacific railway crossing.

In its lower course the valley of the Chariton averages 3 miles in width, and is well timbered with water-oak, burr-oak, hickory, maple, and birch. The river itself is 125 feet wide, and is a sluggish stream, with only occasional riffles; no rafting is done, and the channel is much choked with permanent accumulations of drift, called "rack-heaps". The bed is very muddy, and the banks are of alluvial soil, ranging from 10 to 20 feet in height above low water. Where the stream has cut into a bluff the bed is rocky on that side. A good quality of coal is found in the bluffs, and 9 miles above Glasgow (near the mouth) it crops out for 180 yards, and is 20 inches thick.

The flow of the stream is said to hold out very well in the dry season. Heavy freshets occur, as usual with the streams in this section, and the bottoms are occasionally overflowed. There are some small saw- and grist-mills on the minor tributaries, and two or three on the main river, but the latter is practically unused. The saw-mills are generally run by steam. A gentleman at Keytesville, familiar with the portion of the river in Chariton county, stated that in the dry season it would carry a three-run mill, but without affording much surplus power; he also said there were five available mill-sites in that county on the stream.

Regarding the upper portions of the Chariton and Grand rivers Dr. White says, in the *Geology of Iowa:*

> Both rivers rise and run for the first 25 or 30 miles of their courses upon the Drift deposit alone. The first strata that are exposed by the deepening valleys of both these streams belong to the Upper Coal Measures, and they both continue upon the same formation until they make their exit from the state, near the boundary of which they have passed nearly or quite through the whole thickness of that formation down to the top of the Middle Coal Measures. Therefore, as might be expected, both these streams are very similar in their general characters so far as their Iowa portions are concerned. Their valleys are usually pretty well defined; but sometimes the surrounding high land slopes for a mile or more gently toward the stream. They gradually deepen from their upper portions downward, so that within 15 or 20 miles they have reached a depth of nearly 150 feet below the general level of the adjacent high land, which depth they retain with little increase until they pass beyond the limits of the state, because the general slope of the country is nearly concurrent with the slope of the streams.

Estimated volume and horse-power of the Northern Missouri tributaries of the Missouri river.

Stream.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.									
Big Tarkio:										
West of Homer	416	0.025	10	11	0.040	15	17	0.070	30	34
At mouth	543	0.025	15	17	0.040	20	23	0.070	40	46
Nodaway:										
At Hepburn	756	0.025	20	23	0.040	30	34	0.070	50	57
At Quitman	1,469	0.025	40	46	0.040	60	68	0.070	100	114
At mouth	1,886	0.025	50	57	0.038	70	80	0.070	130	148
Platte:										
At Conception	501	0.030	15	17	0.030	15	17	0.060	30	34
Above One Hundred and Two river	707	0.025	20	23	0.030	20	23	0.060	40	46
At mouth	2,487	0.015	40	46	0.020	50	57	0.040	100	114
One Hundred and Two river:										
At Maryville	517	0.030	15	17	0.030	15	17	0.060	30	34
At mouth	784	0.025	20	23	0.030	25	28	0.060	45	51
Grand:										
At Chillicothe	4,935	0.015	75	85	0.020	100	114	0.040	200	227
At mouth	7,932	0.015	120	136	0.018	140	160	0.035	280	318
West Fork:										
At Albany	406	.....	.....	.....	0.020	10	11	0.050	20	23
At Gallatin	2,241	0.015	30	34	0.020	45	51	0.045	100	114
At mouth	2,678	0.015	40	46	0.020	50	57	0.045	120	136
Big river, at Elm Flat	323	.....	.....	.....	.....	.....	.....	0.030	10	11
Thompson's fork, above Weldon river	1,155	0.015	20	23	0.020	20	23	0.045	50	57
Weldon river, above Thompson's fork	597	0.015	10	11	0.020	10	11	0.040	25	28
Total, East Fork:										
At Trenton	1,752	0.015	30	34	0.020	35	40	0.040	70	80
At Chillicothe	2,257	0.015	35	40	0.020	45	51	0.045	100	114
Medicine river	443	.....	.....	.....	.....	.....	.....	0.030	10	11
Locust creek	615	.....	.....	.....	.....	.....	.....	0.030	20	23
Yellow creek	690	.....	.....	.....	.....	.....	.....	0.030	20	23
Chariton:										
East of Centerville	685	0.030	20	23	0.040	30	34	0.080	55	63
West of Kirksville	1,394	0.020	30	34	0.025	35	40	0.055	75	86
At Hannibal and Saint Joseph railroad crossing.	1,684	0.020	30	34	0.025	40	46	0.055	90	103
At mouth	2,900	0.020	60	68	0.025	70	80	0.055	160	182

The rainfall appears to vary considerably in its distribution among the different seasons, over the country drained by these rivers, but, for the section as a whole, may be regarded as approximately 8 inches in spring, 12 in summer, 8 in autumn, and 5 in winter, giving a total of 33 inches for the year. The average winter temperature for the same district is about 28° Fahrenheit.

Power utilized on the Northern Missouri tributaries of the Missouri river.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Big Tarkio	Missouri	Missouri	Atchison	Flour and grist	2	15	66
East Tarkio	Big Tarkio	....do	....do	....do	1	11	22
Do	....do	Iowa	Page	....do	2	20	45
Little Tarkio	Missouri	Missouri	Holt	....do	1	14	10
Nodaway	....do	....do	....do	....do	1	8	20
Do	....do	....do	Andrew	....do	1	6	30
Do	....do	....do	Nodaway	....do	4	25	103
Do	....do	Iowa	Page	....do	3	21	82
Do	....do	....do	Montgomery	....do	2	24	54
Do	....do	....do	Cass	....do	1	9	20
Small streams	Nodaway	Missouri	Holt	....do	1	30	20
Do	....do	....do	Nodaway	....do	1	6	16
Do	....do	Iowa	Page	....do	1	8	24
Middle Nodaway	....do	....do	Adams	....do	3	22	80
						317	

Power utilized on the Northern Missouri tributaries of the Missouri river—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Platte	Missouri	Missouri	Platte	Flour and grist	2	18	103
Do	do	do	Buchanan	do	3	23	136
Do	do	do	Andrew	do	4	37½	145
Do	do	do	do	Saw	1	3½	10
Do	do	do	Nodaway	Flour and grist	1	14	76
Do	do	do	Worth	do	1	8	18
Do	do	Iowa	Taylor	do	1	10	25
Do	do	do	Ringgold	do	1	8	23
One Hundred and Two river	Platte	Missouri	Buchanan	do	2	21	125
Do	do	do	Andrew	do	3	23½	65
Do	do	do	Nodaway	do	3	26½	93
Small streams	do	do	Clay	do	1	9	50
West Grand	Grand	do	Livingston	do	1	8	24
Do	do	do	Daviess	do	3	(?) 21	100
Do	do	do	Gentry	do	3	19	76
Do	do	do	Worth	do	2	14	40
Small streams	West Grand	do	do	do	1	10	30
East Grand	Grand	do	Livingston	do	3	23½	95
Do	do	do	Grundy	do	2	14½	40
Thompson's fork	East Grand	do	Harrison	do	2	14	150
Do	do	Iowa	Decatur	do	3	22	95
Do	do	do	Union	do	1	9	10
Weldon	Thompson's fork	Missouri	Mercer	do	2	15½	94
Do	do	Iowa	Decatur	do	1	5	16
Medicine	Grand	Missouri	Livingston	do	1	8	14
Do	do	do	Grundy	do	2	17½	36
Locust	do	do	Linn	do	3	28	90
Do	do	do	Sullivan	do	3	25	86
Small streams	do	do	Caldwell	do	2	16	15
Do	do	do	Carroll	do	2	20	52
Chariton	Missouri	do	Macon	Flour, grist, and lumber	1	6	51
Do	do	Iowa	Appanoose	Flour and grist	1	10	37
Mussel fork	Chariton	Missouri	Chariton	do	2	18	60
Do	do	do	do	Flour, grist, and lumber	1	7	57
Do	do	do	Macon	Saw	1	9	10
Small streams	do	do	Chariton	do	1	9	25
Do	do	do	Randolph	do	1	9	25
Do	Missouri	do	Holt	Flour and grist	1	30	10
Do	do	do	Platte	do	2	26½	36
Do	do	do	Carroll	do	2	12	45
Do	do	do	Boone	do	3	78	78
SUMMARY.							
Big Tarkio	Missouri	Missouri		Flour and grist	2	15	66
Tributaries	Big Tarkio	Missouri and Iowa.		do	3	31	67
Little Tarkio	Missouri	Missouri		do	1	14	10
Nodaway	do	Missouri and Iowa.		do	12	93	309
Tributaries	Nodaway	do		do	6	66	140
Platte	Missouri	do		Flour and grist (1 saw-mill).	14	122	536
One Hundred and Two	Platte	Missouri		Flour and grist	8	71	283
Small streams	do	do		do	1	9	50
West Grand	Grand	do		do	9	62	240
Small streams	West Grand	do		do	1	10	30
East Grand	Grand	do		do	5	38	135
Thompson's fork	East Grand	Missouri and Iowa.		do	6	45	255
Weldon	Thompson's fork	do		do	3	20½	110
Medicine	Grand	Missouri		do	3	25½	50
Locust	do	do		do	6	53	176
Small streams	do	do		do	4	36	67
Chariton	Missouri	Missouri and Iowa.		do	2	16	88
Mussel fork	Chariton	Missouri		Flour, grist, and saw	4	34	127
Small streams	do	do		do	2	18	50
Do	Missouri	do		Flour and grist	8	146½	169
Total					100	925½	2,958

IV.—TRIBUTARIES ON THE WEST SIDE OF THE MISSOURI RIVER, BELOW FORT RANDALL.

THE NIOBRARA RIVER.

Although my own visits to the tributaries which the Missouri receives from the west did not extend north of the Platte river, there are certain peculiar features of the Niobrara, described in published accounts, which lead me to make mention of it.

This river heads in the eastern part of Wyoming territory, 30 or 40 miles east of Fort Fetterman. From this point it takes a general easterly course, and enters the Missouri river near the town of Niobrara, in exactly the same latitude as that of its source, namely, 42° 47′ north. Its entire length, measured along the general line of its flow, is about 365 miles. For the last 55 miles of its course it forms the boundary between Nebraska and Dakota, which boundary is continued for 35 miles by the Keya Paha, a tributary of the Niobrara. It is not possible to fix accurately upon the water-shed lines, owing to the incompleteness of present maps, but the area drained is approximately 13,200 square miles. Of this 1,750 square miles belongs to the Keya Paha river, and 2,200 to the Snake, the most important affluents.

The finest description of the Niobrara is to be found in the *Preliminary Report of Explorations in Nebraska and Dakota, in the years* 1855–1857. This report was made by Lieutenant (now General) G. K. Warren, Corps of Engineers, who said concerning the river:

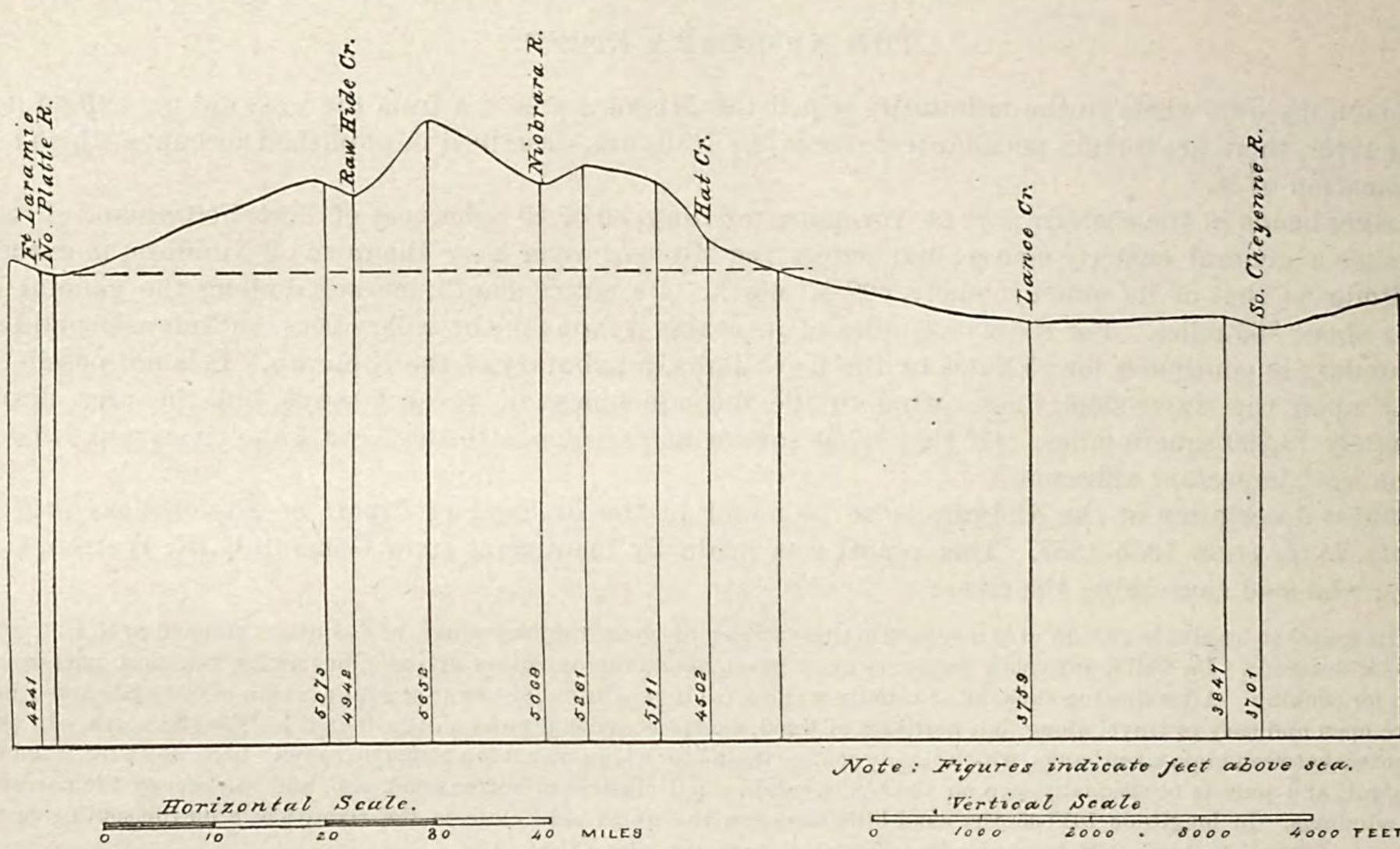
> From its source to longitude 103° 15′ it is a beautiful little stream of clear, running water, of a width of from 10 to 15 feet, gradually widening as it descends. Its valley furnishes here very good grass, abounding in rushes or prele, but is for the most part destitute of wood, even for cooking. After flowing thus far, it rapidly widens, till in longitude 102° 30′ it attains a width of 60 to 80 yards; its valley is still quite open and easy to travel along, but destitute of wood, except occasional pines on the distant hills to the north. In longitude 102° 30′ it enters between high, steep banks, which closely confine it, and for a long way it is a complete cañon; here, however, wood becomes more abundant, and pine is occasionally seen on the bluffs, while small clusters of cottonwood, elm, and ash occupy the narrow points left by its windings. In longitude 101° 45′ the sand-hills come, on the north side, close to the river, while on the south side they are at the distance of from 1 to 2 miles off, leaving a smooth road to travel on along the bluffs.
>
> The bluffs gradually appear higher and higher above the stream as it descends, until they reach the height of 300 feet. The sand mostly ceases, on the north side, in longitude 100° 23′; but it lies close to the stream on the south side, nearly all the way to Wazi-honska. Throughout this section, lying between longitude 102° and longitude 99° 20′, a distance of 180 miles, the Niobrara is in every respect a peculiar stream, and there is none that I know of with which it can be compared. It flows here between high rocky banks of soft white and yellowish calcareous and siliceous sandstone, standing often in precipices at the water's edge, its verticality being preserved by a capping of hard grit. As you approach from the north to the south, there are no indications of a river till you come within 2 or 3 miles of the banks, and then only by the trees, whose tops occasionally rise above the ravines in which they grow; so completely is it walled in by the high walls which inclose its narrow valley. It seems as if it had resulted from a fissure in the earth's crust, and now flows at a depth of about 300 feet below the general level of the prairie.
>
> The soft rock which forms the bluffs is worn into the most intricate labyrinths by the little streams, all of which have their sources in beautiful gushing springs of clear, cold water. In these small, deep valleys, the grass is luxuriant; pine, ash, and oak are abundant. From longitude 99° 20′ to the mouth, an extent of about 90 miles, the bottoms will probably average a width of a quarter of a mile, are susceptible of cultivation, and cottonwood, oak, walnut, and ash will furnish settlements with all the timber and fuel they will need. The river banks seem to present no good building stone, nor did we, though searching diligently, discover any signs of coal or other valuable minerals.
>
> The Niobrara is a very shallow and "swift-flowing stream", as the Canadians say, "*l'Eau qui Court,*" abounding in rapids in two-thirds of its upper course, and in its middle portion filled with small islands. In the lower portion its width exceeds that of the Missouri river, and is spread out over sand-bars. The bed in the broad portions is quicksand, and difficult to ford. Its waters rapidly increase in volume through its middle portion from the multitude of springs and streamlets that constantly flow into it from the foot of the bluffs and out of the ravines. The traders of the American Fur Company have navigated it with skin boats, carrying peltries from their former trading-house near Snake river, and the stream might permit of rafting if the timber should be found of quality, quantity, and accessibility to defray the expenses.

The Keya Paha, or Turtle Hill, river is the most important tributary on the north side of the Niobrara. It is about 120 miles long, and has a width of 50 yards at the mouth. The valley is one-half to three-quarters of a mile wide, with good soil and a limited quantity of cottonwood timber. The river bed is sandy, and the waters are clear and sweet.

Snake river, on the south side of the Niobrara, is some 30 yards wide toward the mouth, and has considerable pine timber along its bluffs. There are numerous other small streams entering the main river at various points, which are in general clear and swift-running; but owing to the peculiar formation of the Niobrara basin, there are, with the exception of the Keya Paha and Snake, no tributary streams of much length.

A peculiar feature of the main stream is the position it occupies upon a ridge. Regarding this subject Professor Aughey remarks in his *Sketches of the Physical Geography and Geology of Nebraska:*

A large part of the entire middle portion of the Niobrara river, as first observed by General Warren, flows lengthwise of an anticlinal ridge. In the cañons, for example, the rocks dip away from the river on each side. In places where I had opportunity to measure the angle, their inclination away from the stream amounted to from 10° to 15°. It is probable that the river has been outlined only since the close of the submergence that attended the Glacial age. Flowing along this anticlinal ridge, where it first emerged, it has continued in its old rut as the continent was rising, cutting down its bed about as rapidly as the uplifting took place. The cutting of the river still continues, though its rate is uncertain. As would be expected, the tributaries of the Niobrara that flow into it from the north or south are very short. The larger ones invariably flow parallel, or nearly parallel, to it. In the cañon region, in going to the Niobrara, when within 12 or 15 miles of it, I invariably found myself going up hill. When the river was reached, it lay from 150 to 400 feet below.



PROFILE ACROSS HEADWATERS OF NIOBRARA RIVER.

The phenomenon which has been described is plainly illustrated in the profiles accompanying certain reports by Captain W. S. Stanton, Corps of Engineers. Several of these profiles show the elevated position of the river, and from them I have selected one near the headwaters, where this feature is especially prominent.

The slope of the river is approximately shown in the following table:

Slope of Niobrara river.

Locality.	Elevation above sea.*	Fall between points.	Distance between points.†	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near source	5,069			
		487	42	11.60
Latitude 42° 34′, longitude 103° 57′	4,582			
		464	34	13.65
Latitude 42° 26′, longitude 103° 18′	4,118			
		1,428	130	10.98
Mouth of Snake river	2,690			
		730	97	7.53
Mouth of Keya Paha	1,960			
		720	52	13.85
Mouth of Niobrara	1,240			

* Authority for elevations: For the first three, Captain W. S. Stanton; for the last three, Professor Samuel Aughey.
† By map measurement, and probably much less than the true water distances.

South of the Niobrara, and toward the headwaters of the Loup and Elkhorn rivers, is a region containing many sand-hills. They are of a somewhat conical shape, varying in height from a few yards to several hundred feet; their sands are partially movable, and by the action of winds they have been carved into very curious forms. In the same region there are great numbers of small lakes, ponds, and sloughs; these are underlaid by an

impervious clayey stratum, so that the only escape for their waters is by overflow or evaporation. Some drain into the streams, but most have no visible outlet. In the section occupied by these lakes and sand-hills, the temperature often rises extremely high during the summer months, and thunder storms are of almost daily occurrence.

Judging from the records at Fort Randall and Fort Laramie, the rainfall over the basin of this river is about 5 inches in spring, 5½ in summer, 3 in autumn, 1½ in winter, and 15 inches for the year. I shall attempt no estimate of the low-water volume of the stream; the only record of any gauging of which I can learn is one furnished me by Professor Aughey, who measured the discharge in July, 1877, when the river was at a high stage, and found it to be 15,760 cubic feet per second at the mouth, or at the rate of 1.19 cubic feet per second per square mile of drainage area.

Steel creek, in Knox county, a tributary of the Niobrara, has one small grist-mill, using 20 horse-power, but the main river is wholly unemployed. It lies in a very sparsely settled region, the combined population of the three counties of Knox, Holt, and Sioux, which adjoin it on the south, being but about 7,700. The basin of the river is at present entirely without railroads; a branch of the Chicago, Milwaukee and Saint Paul road, in southeastern Dakota, extends to a point on the Missouri nearly opposite the mouth, and the Sioux City and Pacific Railroad Company has two lines following up, respectively, the main Elkhorn and its north branch, and approaching within about 20 miles of the Niobrara on the south; these may in time be prolonged to the course of that river.

THE PLATTE RIVER.

So far as regards extent of area drained, the Platte is the most important tributary of the Missouri. It is formed by two forks, the North Platte and the South Platte, which rise, respectively, in northern and in central Colorado, and unite somewhat southwest of the center of Nebraska. From the point of junction the main river pursues a winding course to the east across the state, and empties into the Missouri river at Plattsmouth; its length between these points is, by general course, 285 miles. Its entire drainage basin comprises about 90,000 square miles, of which, in round numbers, 36,000 belongs to the North Platte and 24,000 to the South Platte. The lower course of the river is through a section fairly well settled, but advancing westward the population becomes more scattered, and beyond Fort Kearney few places of importance are found off the line of the Union Pacific railroad, which follows the valley from near the mouth to North Platte and then continues along the course of the South Platte river. Plattsmouth, at the mouth, has a population of 4,175; and above this the larger places along the river are Fremont, Schuyler, Columbus, Grand Island, Kearney Junction, and North Platte, containing from 1,000 to 3,000 inhabitants each. According to the statistics of Mr. Gannett, the population of the entire basin of the Platte has increased from about 69,000 in 1870 to 265,000 in 1880.

The course of the river lies through a broad and level bottom, rather sandy in places, but, on the whole, fertile and well suited to the raising of corn, wheat, potatoes, and grass. The rainfall is somewhat deficient and uncertain, however, and partial failures of crops from that cause are not uncommon. The bottom-land is bordered by bluffs, probably varying from 50 to 300 or 400 feet in height; at some points there is a gradual ascent to their summits from the river, while at others they rise more abruptly. The valley inclosed by them varies considerably in width, but in the vicinity of the mouth of the Loup ranges from 3 to 8 miles across. The river occasionally runs close to the bluffs, but usually maintains its position well out in the bottom.

The Platte is a broad and shallow stream; at Central City it is three-quarters of a mile to a mile wide, and for 100 miles above Columbus the width between banks is estimated to average half a mile. The width of running water, however, in that section, is much less at an ordinary stage; the main channel is not more than 150 feet wide and 2 to 3 feet deep, while over the remaining width there are pools and little rivulets interspersed among sand bars. Opposite the town of Grand Island the river divides into two main channel-ways, each about 2,100 feet across, and numerous minor channels of small width; in order to cross the entire stream at this point the county of Hall was obliged to build nine separate bridges, spanning these different divisions of the main river. The banks are generally sandy and low, averaging not more than 3 feet in height. The bed is of quicksand and very shifting; a person may easily ford the stream with a team at one hour, but on returning in a short time will find, if there has been meanwhile a change in the wind, as from north to south, the channel forced to the north shore, and his team will sink at every step. When roiled from any cause, the water becomes yellowish in color and is very opaque.

The Platte has a rapid descent and a swift current. The elevations in the accompanying table are by railroad surveys, and do not correspond exactly to the water surface; still they will give a very good idea of the general slope.

Elevations on the Platte river.

[From *Physical Geography and Geology of Nebraska.*]

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
North Platte†	2,825			
		419	63	6.65
Plum creek†	2,406			
		263	34	7.74
Kearney†	2,143			
		420	66	6.36
Central City†	1,723			
		351	55	6.38
Schuyler†	1,372			
		437	86	5.08
Plattsmouth ‡	§935			

* Map measurement along river's course.
† Elevation of rails, Union Pacific railway.
‡ Elevation of rails, Burlington and Missouri River railroad.
§ Furnished by T. E. Calvert, esq., chief engineer.

The principal freshet in this river occurs in June, and is due to the melting of snow at its headwaters in the Rocky mountains, and the heavy rains of late spring and early summer. Although the banks are very low and the freshet volume is large, still the width and slope are such that the stream seldom overflows to an important extent; even in high water the depth in the vicinity of Grand Island only ranges from 2 to 6 feet. Following the June rise the volume rapidly diminishes, and the river at length either disappears entirely in its sandy bed or becomes reduced to a chain of pools. It may be lost to sight for some distance, and then appear again where forced up by the position of the underlying strata. Mr. W. W. Watson, civil engineer, of Fairbury, Nebraska, stated that he had traveled along the Platte and found it dry for 300 miles above the mouth of the Loup. Although the river sinks away in the sand, its waters are yet leaching along through the bed, but, of course, with a very slight current; the current, can, however, be perceived if a trench be dug 3 or 4 feet deep, at which depth water will always be found. The phenomenon which has been described is claimed to have become more marked during the past few years, owing to the increased use of the waters of the South Platte for irrigation in Colorado.

Since a large volume of water is thus lost to sight, the question naturally arises, What becomes of it? A portion of it probably leaches along in the manner already spoken of, and either is brought to the surface of the river bed again, or else continues its flow underground along the general course of the stream, at length finding its way into the Missouri. But another portion, doubtless much the greater, escapes by underground drainage to the south into the Republican and Blue rivers. The general slope of the surface of Nebraska is to the east, but in the southeastern portion of the state the slope becomes southeast. In that section the Platte receives hardly a tributary of any length from the south, except Salt creek, which empties 25 or 30 miles from the mouth; much of the way the southern water-shed is but 2 or 3 miles from the stream, and for two-thirds of the distance from North Platte to the mouth it is not, on the average, more than 10 miles from its course; the same feature continues to a greater or less degree along the South Platte into Colorado. The southeastern part of Nebraska is mainly covered by the Loess or Bluff deposit, underlaid by the sand, gravel, and clay of the Drift; the surface materials and prevailing slope are thus seen to be favorable to underground drainage, and the proofs of its actual occurrence are numerous and convincing.

Even when the river is at a fair stage, Professor Aughey has discovered that the volume diminishes largely between North Platte and the mouth. Thus, as the mean of five determinations, he found the discharge at the mouth to be 18,354 cubic feet per second, "at the close of the June flood, after the waters had assumed the level they had previous to that rise"; two days later, having in the meantime proceeded to the junction of the North and South Platte, he measured a discharge of 22,953 cubic feet per second in the main stream at the latter point. These measurements show, not a gain, but an actual loss in volume of 4,600 cubic feet per second between North Platte and the mouth; this loss cannot be due to evaporation, for the Loup and the Elkhorn add much more to the volume than it is at all probable could be lost in that manner. This is not necessarily a proof that the water lost passes into the rivers to the south; but it is to the point, however, that the Republican and the Blue, although neither of them reaches to the mountains or has a large snowfall over its basin, answer promptly to a rise in the Platte by an increase in their own volume, whether that stream is swollen from melting snows in the Rocky mountains or from any other cause.

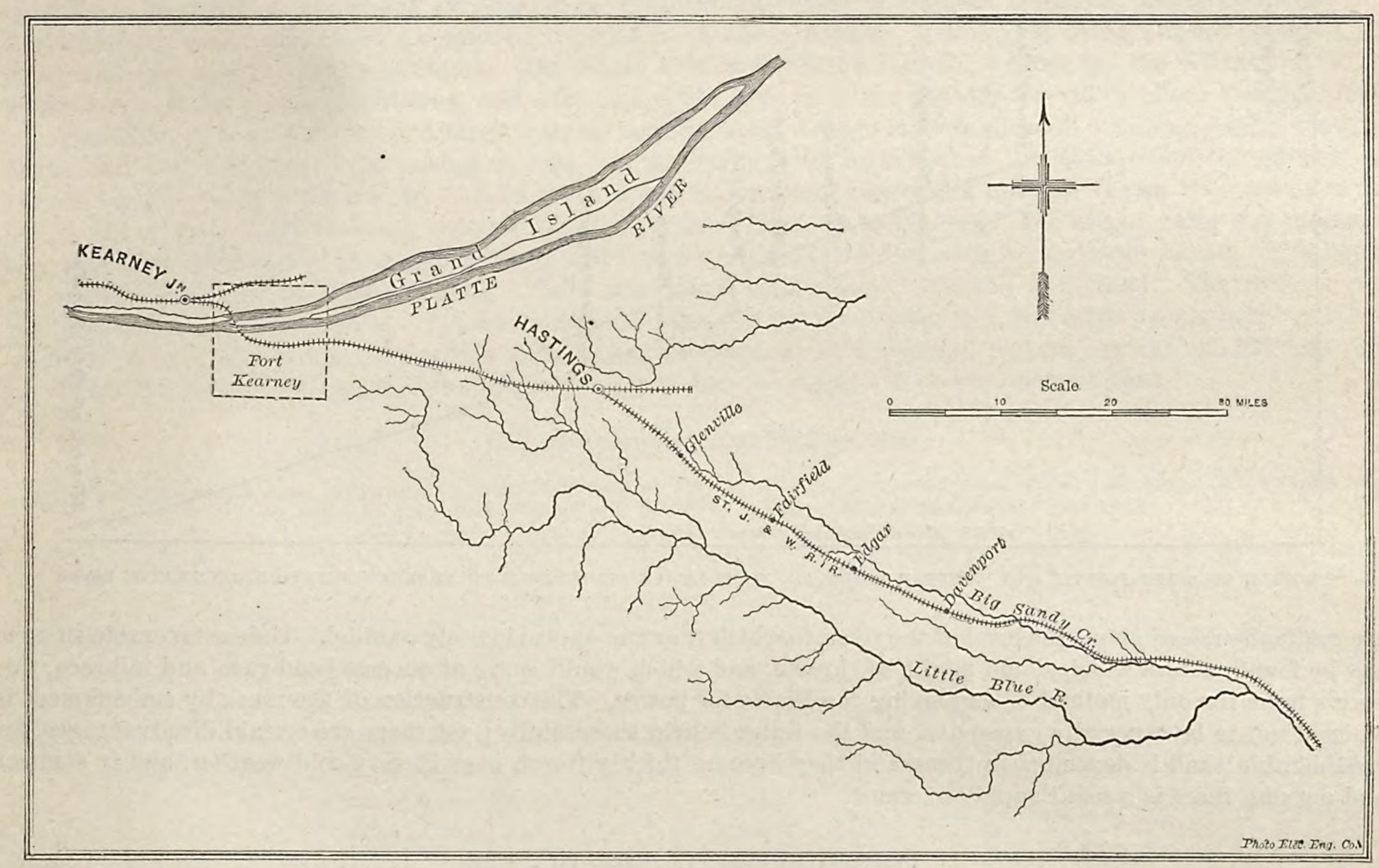
Regarding the phenomenon of underground drainage, Professor Aughey says:

The average volume of water at North Platte is greater than at the mouth, though it receives in the mean time some large tributaries, the most important of which are the Elkhorn, Papillion, Shell creek, Loup, and Wood river. A few held that this was caused by evaporation. The tributaries, however, that enter the Platte from the north more than supply the waste from this cause. The explanation of this phenomenon is found in the character of the bottom, and its continuation with the Drift under the Loess as far as to the Republican. It will also be seen in the lists of elevations that have been given that the general level of the Republican is 352 feet below that of the Platte. There is therefore a descent from the Platte to the Republican, and along such a formation that there is easy

drainage from the one into the other. That there is such a drainage upon an extensive scale I have no doubt. Wading in the Republican in August, as I have done for many miles at a time, I noticed on the north side water oozing out of the Drift continuously every few feet in places, and rarely at greater intervals than every few rods. Nothing of the kind was noticed on its southern shore. Where tributaries of the Republican from the northwest cut deep enough to strike the Drift they share in the reception of this water from the Platte. Few, however, do this.

This escape of the drainage water through the river banks, observed on the Republican by Professor Aughey, has also been noticed on the Big Blue in the vicinity of Beatrice, and very likely at other points; in the former locality it is said that it can frequently be seen issuing in a thin sheet from the banks.

A striking proof of this flow southward from the Platte is afforded by the profile and borings along the line of the Saint Joseph and Western (*a*) railroad. This road, passing southeasterly from Hastings, follows down the valley of Big Sandy creek till that stream unites with the Little Blue. Along the railroad wells were sunk at various points in order to obtain water for supply-tanks. An accompanying map shows the geography of this section,



MAP ILLUSTRATING DRAINAGE FROM THE PLATTE RIVER.

while in another cut are illustrated the profile of the road and the positions of the wells. The profile was furnished me by Mr. W. W. Watson, of Fairbury, who also supplied the following extract from an article by Mr. E. Whiting, formerly chief engineer of the Saint Joseph and Denver railroad, which fully explains the proof supplied by the profile:

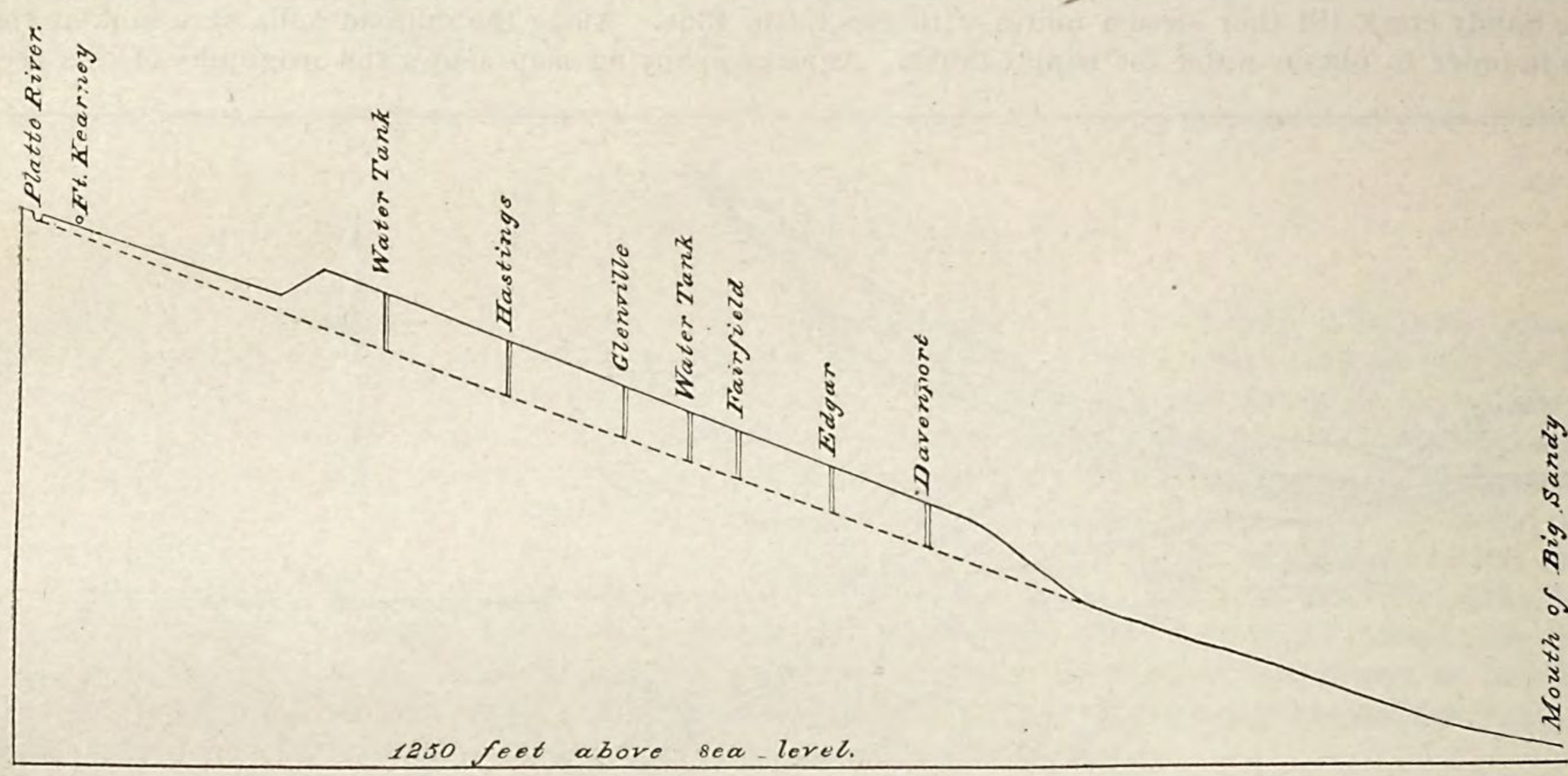
The Big Sandy at its mouth is a stream 30 to 40 feet wide, ordinarily 2 to 4 feet deep, running with a swift current, the fall being from 6 to 10 feet per mile; the water is very clear, pure, and soft. This volume is maintained even in dry seasons, and for a distance of 8 or 10 miles up the stream, excepting only in cases of melting snow or heavy rains at or near its head; at such times the river rises suddenly, the water becomes turbid and muddy, receding almost as quickly as it came up, after the cause of its rise has abated. About 15 miles from its mouth the water ceases entirely to run (except in case of floods), standing only in pools. Between its mouth and where it ceases to flow it receives no tributaries of running water, and but few springs are visible.

The ridge or plateau traversed by the railroad, between the Big Sandy and the Little Blue, is apparently very flat or level, having a gradual rise to the northwest of about 8 feet per mile. At the stations of Davenport, Edgar, Fairfield, Glenville, and Hastings wells were bored; also wells were dug to supply a tank between Fairfield and Glenville, as also beyond Hastings. At depths, shown on the profile, varying from 108 to 112 feet, water in great abundance was found, clear, cold, and pure, similar to the water in the Big Sandy. By looking at the profile it will be seen that a line drawn through the bottom of these wells would be in almost a straight line, falling to the southeast about 8 feet per mile, or the same as the surface of the ridge. If this line be continued, with the same inclination, eastwardly from Davenport, it would strike the bed of the Big Sandy at about the same point where the water begins to flow permanently in that stream. The same line, continued northwesterly, would correspond to the bed of the Platte near Fort Kearney. The bed of the Sandy is composed of the same kind of sand, gravel, and pebbles as that found at the bottom of the wells on the ridge. Similar sand and gravel compose the bed of the Platte.

a Formerly Saint Joseph and Denver.

Whatever ice forms in the Platte is said usually to waste away before breaking up. The river has absolutely no value for navigation; no rafting is done, and only a slight fringe of timber is found upon the banks. The only use, in fact, to which the main river is put is to furnish power to a few flouring- and grist-mills of moderate size, mainly located in Merrick county. The damming of the stream in the ordinary manner is evidently impracticable, and the method adopted at these mills is to divert sufficient water into the races by some rude means, as, for instance, a short wing-dam of brush. The races run between embankments of earth thrown up on either side, and

[Compiled from report of E. Whiting, formerly chief engineer Saint Joseph and Denver railroad, by W. W. Watson, Fairbury, Nebraska. Vertical scale, 400 feet to 1 inch. Horizontal scale. 20 miles to 1 inch.]



PROFILE OF SAINT JOSEPH AND WESTERN RAILROAD, FROM LITTLE BLUE RIVER TO KEARNEY JUNCTION, ON PLATTE RIVER.

are gradually raised above the level of the river, to which they run approximately parallel. Unless favorable sloughs can be found, across which dams might be thrown, and which would serve at once as head-race and tail-race, this seems to be the only method of employing the Platte for power. The construction of the races by embankment is claimed not to be especially expensive, and the water is held successfully; yet there are certain disadvantages, for considerable sand is deposited in them, and they become thickly frozen over in very cold weather, and in summer and autumn there is a scant supply of water.

TRIBUTARIES OF THE PLATTE.

In describing the tributaries I shall take up the more important ones in order from the mouth of the Platte.

The first to be noticed is Salt creek, a small stream joining the Platte from the south at Ashland, and draining, principally, the counties of Lancaster and Saunders. It has a length of perhaps 45 miles by general course, and drains 1,630 square miles. A line of the Burlington and Missouri River railroad follows the creek to its mouth from Lincoln, capital of the state, and the most important town on its course.

The creek receives its name from the salt springs and salt marshes found near its upper waters. Elevations on the railroad show a descent of 62 feet from Lincoln to Ashland, but the actual fall in the water surface of the stream I am unable to give. In an ordinary stage of water the width near the mouth is 75 feet, and there is a current of 3 or 4 miles an hour. The stream is very crooked, but never overflows its banks.

The lowest mill on the stream is at Ashland, near the mouth, where power is employed by a four-run flouring-mill, having a head of 7 feet and using 40 horse-power; about 8 horse-power is also in use by a small wind-mill factory at the opposite end of the dam. There is an abundance of water for these establishments throughout the year, and a considerable surplus also; for two weeks more or less trouble is experienced with backwater from the Platte. The dam was built in 1864, and is a framed structure resting upon and bolted to a bed of limestone. It is 240 feet long, 7 feet high, and is claimed to set back the river 11 miles by land, or 33 miles by water, thus forming a pond having an average width of 60 feet.

Some 7 miles above Ashland Rock creek empties in from the west. It is a small stream, and is said to have one mill of two runs and another of one run. On the main stream there is a mill at Waverly, one of four runs and one of two runs at Lincoln, and one of two runs at Roca. The dams are usually of brush, and range from 50 to 75 feet in length, with a height of 10 or 12 feet. Bragg's mill, at Lincoln, has four runs of stone, and uses a 34-inch Leffel

wheel running under a head of 11 feet. The dam is 50 to 60 feet long, 11 feet high, and was built in 1880 at a cost of $350. It was constructed of brush in the usual manner, except that the successive layers were secured by lines of stakes running across the stream and having stout withes interwoven among them.

The bed of the stream is sandy or muddy, and the banks are of loam, 10 to 20 feet high. The flow is quite steady and adapts the stream very well to milling purposes; but the fall is slight, and it is thought there is not much available power unused in the more important part of its course.

THE ELKHORN RIVER.

The Elkhorn rises in northern Nebraska, and taking a southeasterly direction empties into the Platte about 30 miles above its mouth. Its principal tributaries are the North Branch, and Maple and Logan creeks. The length, by general course, is 215 miles, and the entire area drained 6,732 square miles. The greater part of this section is sparsely settled, but is increasing in population with the extension of railroad facilities; the counties directly bordering the main river have a combined population of about 82,000. West Point is the largest place on the river, and has about 1,000 inhabitants. The Sioux City and Pacific railroad follows up the Elkhorn from its lower course nearly to the headwaters, and a branch of the same road also ascends the valley of the North Branch.

The Elkhorn has its source in a large tract of marshy land; thence it flows through a rolling prairie country, fertile and well adapted to the raising of corn, but possessing very little timber. It is bordered immediately by bottom-land 1 mile to 3 miles wide, beyond which there is a gradual rise to the upland. From West Point to the mouth the average width between banks gradually increases from 150 to 170 feet. The actual water-way measures less than this, however, in an ordinary stage, and is not more than 115 feet wide in the lower course. The banks are of loam, and have a height of 6 or 8 feet; the bed is sandy, and frequently quicksand. The river is very winding, but has a swift current. Considerable snow falls, toward the headwaters, and drifts deeply in the gulches; about the first of May the melting of this snow causes a freshet, which is assisted by heavy rains; the Elkhorn then runs with full banks, but only once in four or five years does it overflow to a noteworthy extent.

Elevations and slope of Elkhorn river.

[Supplied by Mr. E. Gerber, assistant engineer Sioux City and Pacific railroad. On the profile of the road elevations are referred to the level of Lake Michigan, which is assumed at 581.92 feet above mean tide at New York. See *Report Chief of Engineers*, 1878, page 1409.]

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near O'Neill†	1,960			
		190	36	5.28
Near Antelope†	1,770			
		57	16	3.56
Near Oakdale†	1,713			
		167	27	6.19
Near Marietta†	1,546			
		271	73	3.71
Near Crowell†	1,275			
		106	36	2.94
Near Bell creek†	1,169			
		67	13	5.15
Waterloo‡	1,102			

* Map measurement.
† Water surface at Sioux City and Pacific railroad crossing.
‡ Water surface at Union Pacific railway crossing.

Only a very small amount of power is in use on the Elkhorn, partly on account of a lack of demand, and partly from the difficulty of maintaining dams. The sandy nature of the bed is certainly an objection, but brush dams are in successful use on similar streams elsewhere, and would doubtless answer their purpose equally well here. There are no abrupt falls and no rapids of any importance, so far as I can learn; but I was informed by a mill-owner who was well acquainted with the river, that once in 4 miles, on the average, an available site could be found where a head of 6 to 8 feet might be secured. The river being very crooked, as stated, it is considered that a fair amount of fall might be obtained at favorable points by running a race across the neck of a long bend.

The few powers which are utilized on the Elkhorn will be given in a subsequent table. The only important development of this stream for water-power is at West Point, at a privilege owned by Mr. John Neligh. At the time of my visit, in December, 1880, about 225 horse-power was employed by a grist- and flouring-mill, a paper-mill, planing-mill, and an establishment for the manufacture of condensed milk. The dam was built in 1867, and is estimated to have cost $7,000. It is 200 feet long, 8 feet high, and is constructed of brush. The quicksand bed on which it rests allows a gradual sinking, and renders necessary an annual outlay of about $1,000 for repairs. A long embankment, running from one end of the dam proper, serves to inclose the river on that side. On the opposite side of the river the bank below the dam is protected from washing by a thick layer of brush and sod. The head on the wheels is about 9 feet. The mills located at this privilege have abundance of water for running at full capacity throughout the year. They are not troubled to a serious extent by ice, nor for more than one week in the year by backwater. The river is said to have a very steady flow, running lowest in winter.

At Neligh, in Antelope county, there is also a four-run flouring-mill, using about 66 horse-power, with a head of 8 feet.

Of the tributaries of the Elkhorn, Logan creek is a good mill stream and probably presents numerous unoccupied sites. It averages 25 to 30 feet in width between banks, and is of fair depth, with a steady supply of water. Maple creek, which joins the Elkhorn from the west not a great way below Logan creek, is of about the same size as the latter, and has one mill. The north branch of the Elkhorn lies mainly in Pierce county and has one mill; the Sioux City and Pacific railroad, which follows its course, descends 63 feet between Pierce and Norfolk, indicating a probable average fall for the river of about 4.5 feet per mile.

SHELL CREEK.

This stream, the next tributary of the Platte above the Elkhorn, comes from the northwest and is about 60 miles long by general course. For 20 miles above its mouth it averages 40 feet in width and 18 inches in depth in an ordinary stage; on its course there are four or five flouring-mills, which obtain heads of 10 to 18 feet, and carry from two to four runs of stone each. According to the levels of the Union Pacific railway, the fall in the water surface from Platte Center to Schuyler is 211 feet, or an average of 7.5 feet per mile.

THE LOUP RIVER.

Two principal forks, rising in northwestern Nebraska, pursue a southeasterly course and unite in Howard county to form the main Loup river; the latter runs easterly and empties into the Platte in the southeastern corner of Platte county. From the source of the Middle Loup the distance, by general course, to the Platte is 260 miles. The Loup drains a total area of 15,553 square miles, having a rolling prairie surface. For 150 miles above the mouth farming land of fair value is found along the bottoms, but farther west it becomes too sandy, especially on the uplands, to be of much worth. No timber of importance occurs along the Loup or its main branches, but on the courses of some of the small tributaries a moderate amount of hard-wood timber grows.

For 30 miles above the Platte the bottom-land averages 4 miles in width, and for 70 miles ranges between 2 and 4 miles. In the lower course the river itself is 300 to 400 yards wide between banks. In an ordinary stage the channel is confined to a width of 50 yards, in which the depth is 4 to 5 feet, while for the remaining distance the depth is 6 inches to 2 feet. The banks are of sandy loam, and range from 2 to 6 feet in height. The bed is of quicksand, a material which seems to underlie the whole surrounding region, and which stretches out in a uniform plane. In the bottoms it is spread out only a short distance beneath the surface. It appears to be considerably stratified, layers of fine quicksand occurring alternately with layers of coarse sand which is almost a gravel. Sixty or 70 miles above the mouth an occasional ledge of rock is encountered in the river bed.

Not enough snow falls at the headwaters to cause an annual freshet such as characterizes the Platte and the Missouri, and it is only after a severe and protracted storm that there is a heavy rise. The banks are seldom overflowed unless there is heavy ice running and a gorge is formed; but this has been known to happen only once in fifteen years on the lower river.

There are no dams on the main stream, and it is not used in any manner for power. Its width, and the treacherous nature of its bed, prevent improvement by dams extending across the river; but by the construction of short wing-dams, sufficient water might probably be diverted into races to be run either between dikes or along high ground, where the latter is near at hand. The flow of the stream is steady, its current good, and its course generally quite straight.

Elevations on Loup river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Head of Middle Loup†	3,230	1,459	195	7.48
Saint Paul‡	1,771			
Columbus‡	1,434	337	62	5.44

* Map measurement.
† Barometric measurement by Professor Aughey.
‡ Water surface at Union Pacific railway crossing.

TRIBUTARIES OF THE LOUP.—These nearly all flow from the northwest. Beaver creek, the first of importance in ascending the stream, empties 18 miles west of Columbus. In an ordinary stage it is 50 yards wide at the mouth, and 2 feet deep; its bed is generally muddy. Cedar creek is 80 miles long by general course, and in its lower portion averages 200 feet in width; its bed is sandy. No power was in use at the time of my visit, though a large mill was being built.

The North Loup is 195 miles long by general course. Its lower valley is of moderate fertility, but above Ord the country away from the river becomes quite sandy. Near the mouth the width between banks averages 400 to 500 feet; in some places the stream spreads over this entire distance, but in others it is confined to half the width or even less. Where running the full width, the mean depth is perhaps 2 feet in an ordinary stage. Above range 30 there are said to be several abrupt falls of 4 to 6 feet each, over shelves of clay; in one locality, no less than four of these occur in 3 miles.

The Middle Loup rises 15 or 20 miles south of the source of the North Loup, and runs approximately parallel to that stream. About 20 miles above their junction it is joined by the South Loup, an important tributary. There is a small grist-mill at Saint Paul, but no other power is used on either of these rivers. The South Loup (*a*) is 100 to 150 feet wide and 2 to 3 feet deep. It formerly had more timber than either of the other streams just described, but this has been largely cut away. In township 18, range 26, there is a sudden fall of about 4 feet over a clay shelf.

The North, South, and Middle Loup are all characterized by a bed usually composed of quicksand, and banks of sandy loam 3 to 5 feet high. They have a swift current, rapid descent (7 or 8 feet per mile), and being fed to a considerable extent by springs, have a well-sustained flow. I was informed that at Ord and at Saint Paul, where power is used by flouring-mills of four and two runs, respectively, the streams are not completely dammed, but some simple device is employed to divert water into canals, which are run far enough to gain the desired head.

The streams to which I have referred are free from serious freshets, except as resulting from severe and long-continued storms; even then they seldom overflow their banks. A foot to a foot and a half of snow falls during December, but commonly wastes away by the middle of January, and has no important effect in raising the streams. These bring down considerable floating ice in the spring, and upon a sudden breaking up it is liable to form a gorge in some bend or narrow, or upon an extensive sand-bar.

The basin of the Loup is very sparsely settled. Columbus, near the mouth of the main river, has about 2,100 inhabitants, but with this exception the largest town is Saint Paul, which has a population of not over 500. A branch of the Union Pacific railway follows the lower river for about 10 miles, and another branch extends from Grand Island to Saint Paul; but neither the Loup nor its principal branches are touched by railroads at any other points.

THE NORTH PLATTE RIVER.

This important stream is formed in northern Colorado. It makes a bold curve to the northward into Wyoming, and then assumes a southeasterly direction, which it maintains to its junction with the South Platte, in Nebraska. Its length by general course is 540 miles; the area drained is approximately 35,574 square miles, of which 2,055 are in Colorado, 25,268 in Wyoming, and 8,251 in Nebraska. The slope of the river is shown in the accompanying table:

Elevations and slope of the North Platte river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
North Park, Colorado†	7,600			
		1,125	‡99	11.36
Fort Steele, Wyoming§	6,475			
		1,636	137	11.94
Point on left bank, near Fort Fetterman.‖	4,839			
		630	69	9.13
Fort Laramie‖	4,209			
		1,445	209	6.91
North Platte§	2,764			

* Map measurement.
† Average elevation of park, as given by Arnold Hague.
‡ From mouth Cheyenne creek.
§ Water surface at Union Pacific railway crossing.
‖ Elevations as given by Captain W. S. Stanton.

The source of this river is in North Park, or rather in the mountains which hem it in on all sides, and which rise 4,500 to 5,000 feet above its general level. The Park is about 35 miles long in a north-and-south direction. In its connection with the Platte it is thus described by Arnold Hague: (*b*)

An undulating surface characterizes the North Park, yet changes in level are so gradual that a greater part of the area, when seen from any elevation that overlooks the basin, appears essentially a plain, only one or two points rising more than a few hundred feet above the Platte bottom. * * * The drainage system of the North Park forms one of its most striking physical features, the entire waters finding their outlet through one stream, the North Platte, whose sources lie high up in the surrounding mountains. Numerous small streams descend from all the steep slopes, which, uniting below into large creeks, flow out toward the center of the basin and make the three main streams, the East, the Middle, and the West Forks, which, at the extreme northern end, come together, forming the North Platte, already a very considerable river, where it breaks through the Archæan wall of the Park.

a Also known as Beaver creek, near the mouth.

b Report by Clarence King on *Exploration of the Fortieth Parallel.*

From North Park the river escapes through a cañon some 20 miles long, in which there is a swift current, with many rapids and falls. After leaving this cañon, its course lies through bottom-land averaging a mile in width, beyond which the country rises into rolling uplands, succeeded by low mountains. Below Fort Steele it is said to run for 16 miles through alkali flats, and then through a rolling, sandy country, till it reaches the Seminoe range, which it pierces, running in a very narrow cañon with numerous rapids and falls. Near the mouth of Deer creek, which empties about 20 miles above Fort Fetterman, there is reported to be an abrupt fall of 50 to 100 feet.

Between the upper cañon and the alkali flats the stream runs through a fine grazing region. It is said that much of the country in this part of Wyoming might be converted into good wheat lands by irrigation, but no important improvements of that kind have yet been introduced. From the upper to the lower cañon the bed and banks are of gravel, and the water is so clear that the bottom may easily be seen, except during high water, when the stream becomes very muddy; the banks are low, averaging not more than 4 or 5 feet in height. The current is very swift, being estimated at 7 or 8 miles an hour, and the flow is comparatively steady from month to month. The average low-water width is about 50 feet, and the depth 1 foot; in high water the river is 200 feet wide and 4 feet deep.

The North Platte runs lowest in winter, when it freezes thickly; as soon as the first spring rise comes, the ice breaks up and runs out. High water prevails from the middle of April till the middle of July; during this period the stream runs bank full, but never overflows to an important extent.

No power is employed upon the main river or upon any of its tributaries, and there will be little demand for such use of the stream for some time to come. If the Platte were to be used, the method of races formed by embankment would probably be found most practicable for improvements, on account of the low banks and the wide bottoms bordering the river. Some of the side streams which head in the mountains are said to be quite well sustained in flow, have clear waters, firm beds, and a rapid fall, ranging from 10 to 15 feet per mile and upward. The slope increases as their sources in the mountains are approached. Jack creek, which is only about 20 miles long in a straight line, falls 1,500 feet between its source and mouth.

Many of the small streams in this section are, however, declared to have no value for power. They carry but a small volume of water in a low stage, often sink away in the sand in their lower courses, and, where they have cut their channels down and formed deep gorges, frequently run through them with very sluggish current.

The Sweetwater, which is represented on the maps as a stream 130 miles long by general course, is said to be quite insignificant in a low stage, running scarcely more than 5 or 10 feet wide and 1 foot deep.

There is no timber worth mentioning along the North Platte from its source to Fort Fetterman. From the latter point to Fort Laramie the fall, as determined by barometric measurement, is 630 feet. (*a*) The width at Fort Laramie is 400 feet, and the depth at low water 3½ feet; the mean range between high and low water is 8 feet. The bed in that locality is composed of clay and bowlders, overlaid by a thin stratum of sand. The banks are of loam, and are firm. Above Fort Laramie the country along the course of the river is rough and broken. Captain Stanton informed me that, while constructing a bridge at the fort, the river above was reported by lumbermen to be so full of rapids and falls that logs could not be floated down without breaking them badly.

In its lower course the North Platte averages somewhat more than half a mile in width; the depth ranges from 1 to 10 or 15 feet in an ordinary stage, and has a mean of 1 or 2 feet. The fall is rapid, and the current, in consequence, swift; the volume is comparatively well sustained. Rain-storms produce no important effect, but the melting of snow in the mountains brings an annual June rise of about 2 feet. Whatever ice is found in this part of the river usually forms in December, and melts away during January. The river bed is composed of fine quicksand; when driven across this seems firm and hard, but if a team is halted it begins to sink and soon becomes locked in the sand. At a depth of 15 or 20 feet a hard layer is encountered which affords an excellent bearing for piles, and which seems to be a clay. The banks are alluvial, average 4 to 5 feet in height, and are never overflowed. Above the junction with the South Platte the bottom-land bordering the stream has a mean width of 5 or 6 miles; for about 20 miles up stream it is cultivated somewhat, and even beyond that distance has value as grass land; but in the latter section the soil is too dry, unless irrigated, for raising most crops, and is devoid of timber.

The valley and basin of the North Platte have but a very sparse population. Forts Steele, Fetterman, and Laramie are the only important points on the upper river; and on the lower course North Platte is the only place of any prominence. The only railroad in this section is the Union Pacific, which crosses the river near its mouth and then follows up the South Platte; it crosses the North Platte again at Fort Steele, Wyoming, but in the intervening distance is most of the way 40 to 80 miles from its course.

The average rainfall on the upper and more important portion of the drainage basin is approximately 4.3 inches in spring, 4.2 in summer, 2.7 in autumn, and 2.5 in winter; making a total of 13.7 inches for the year.

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a For my information concerning this part of the river I am indebted to Captain W. S. Stanton, Corps of Engineers, United States Army.

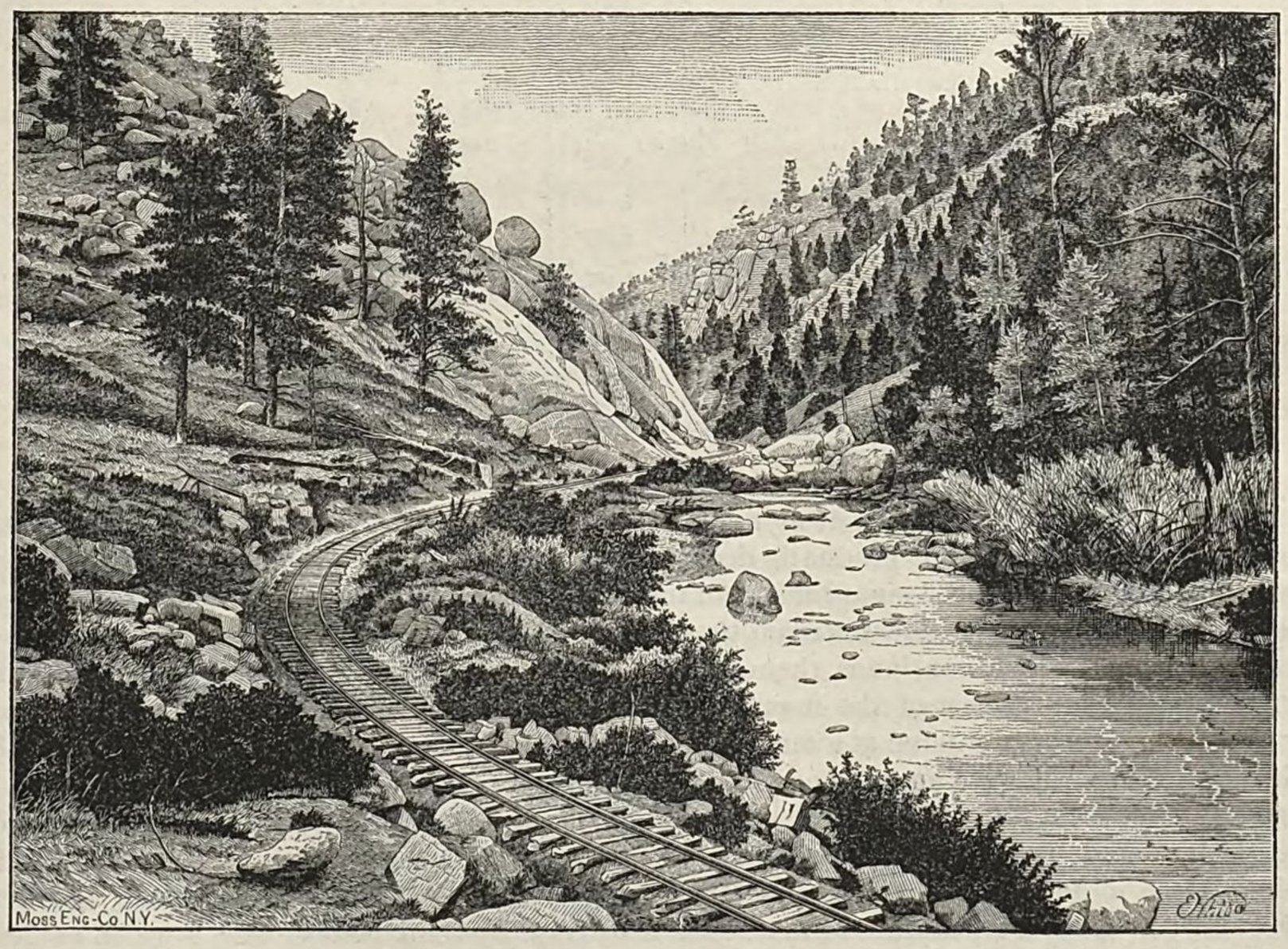
THE SOUTH PLATTE RIVER.

This river has its sources in the central part of Colorado; what is known as the Middle Fork starts from Mount Lincoln, 70 miles southwest of Denver. This locality is of interest as being an initial point of three great drainage systems: the Platte starts to the eastward on its long journey to the Missouri; the Arkansas, taking a course much farther to the south, passes on to the Mississippi; while, flowing to the westward, Eagle river empties into the Grand, which, farther on, merges in the Colorado, and so at length finds its way to the Gulf of California.

From Mount Lincoln the South Platte pursues quite a direct course to the southeast for about 45 miles; it then turns sharply, through more than 90°, and runs northeasterly for 125 miles without deviating 10 miles from an air-line. A short distance beyond Greeley it changes its direction to easterly and follows a more winding course, passing out of Colorado at the northeastern corner of the state, and uniting with the North Platte, in Nebraska, to make up the main river. It has a length by general course of about 400 miles, and a drainage area of 24,468 square miles, comprising 19,292 square miles in Colorado, 1,913 in Wyoming, and 3,263 in Nebraska. The country bordering the whole lower course of the river is very sparsely populated, and on account of the sandy soil and slight rainfall has little or no value for agriculture. Approaching the Rocky mountains, however, numerous streams are met with, mainly those heading in the mountains, which by their steady flow and rapid descent are well suited to use for irrigation; by employing these streams a tract of country 20 to 30 miles wide, running parallel to the base of the mountains and lying principally to the west of the Platte, has been made susceptible of cultivation, and yields large crops of grain.

Above North Platte the only prominent places on the river are Greeley and Denver. The Union Pacific railway follows the valley from the mouth to Julesburg, about 90 miles; it then passes up the valley of Lodge Pole creek into Wyoming; from Cheyenne two routes lead southward to Denver, the easterly one running for about 50 miles near the river; both these roads are owned by the Union Pacific company, which also has a line running up the valley of Clear creek, and another, the Denver, South Park, and Pacific, following the Platte for 25 miles above Denver and then turning up the course of the North Fork. From Julesburg to Greeley, a distance of 140 miles by general course, the river is not approached by any railroad line.

Near the head of the Middle Fork numerous little mountain streams are received, which are important only in spring, running very low at other seasons. Regarding the main portions of the Middle Fork and South Fork I



VIEW NEAR BUFFALO, ON THE DENVER, SOUTH PARK, AND PACIFIC RAILROAD.

have no data, but the general features of those streams can be sufficiently well determined from a description of the North Fork. The latter runs easterly, and is 35 or 40 miles long, by general course. Nearly its entire passage is among the mountains, which are heavily timbered with pine and spruce, and abound in mineral resources, including gold, silver, copper and lead. The fall is very rapid, and, as shown by the levels of the Denver, South Park, and

Pacific railroad, frequently amounts to more than 150 feet in a mile; this descent is in a series of rapids and is without abrupt falls of any consequence. With so great a slope the stream is, of course, a torrent in character. Its bed is rocky and contains many huge bowlders; it varies considerably in width, and ranges, I should say, between 25 and 150 feet. In places its valley widens out somewhat, but usually it is very narrow, being a succession of cañons, the sides of which rise, almost vertically at times, hundreds and even thousands of feet from the water.

There are no mills on this fork, but power could doubtless be used to good advantage, if there were any demand, at points where the valley is sufficiently wide. It is possible to obtain a very large head, and the stream has this advantage in the mountains, that it is not drawn upon for irrigation. There is no danger from ordinary freshets, but occasionally a sudden and heavy fall of rain, called a "cloud-burst", occurs and occasions damage.

Slope of the North Fork and South Platte rivers.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
North Fork.	*Feet.*	*Feet.*	*Miles.*	*Ft. per mile.*
Webster †	9,005			
		422	3.11	135.69
Grant †	8,583			
		541	6.14	88.11
Slaght's †	8,042			
		301	5.42	55.54
Bailey's †	7,741			
		166	2.99	55.52
Estabrook Park †	7,575			
		489	3.83	127.68
Grosson †	7,086			
		152	1.82	83.52
Thompson †	6,934			
		168	3.64	46.15
Pine Grove †	6,766			
		119	2.73	43.59
Buffalo †	6,647			
		169	2.58	65.50
Park Siding †	6,478			
		117	3.23	36.22
Vermillion †	6,361			
		248	4.30	57.67
South Platte †	6,113			
		235	2.67	88.01
Deansbury †	5,878			
South Platte river.		358	6.63	54.00
Platte Cañon †	5,520			
		139	9.56	14.54
Littleton †	5,381			
		149	8.14	18.30
Platte bridge †	5,232			
		34	2.46	13.82
Denver (center Seventeenth street) †	5,198			
		231	22.00	10.50
Near Hughes ‡	4,967			
		306	32.00	9.57
Evans ‡	4,661			
		1,917	231.00	8.30
Mouth of river §	2,744			

* Distances above Denver are by railroad; below Denver they are by map measurement.
† Railroad elevations, Denver, South Park, and Pacific railroad.
‡ Water surface at Union Pacific railway crossing.
§ Water surface, estimated.

On leaving the mountains the Platte soon takes on those features which characterize the remainder of its course. Its slope is quite uniform, but gradually decreases toward the mouth; the current is very swift, especially in high water. The bed, which in the mountains contains many large bowlders, is now composed at first of pebbles, gravel, and some bowlders; farther down stream these are succeeded by coarse sand, and not far below Denver is encountered quicksand, which continues thence to the mouth. It is said that the beds of the Platte and its tributaries, in the open country east of the mountains, are composed of sand to a great depth, while beneath the surrounding country rock is encountered at a moderate distance down; if this is true, it indicates that these streams flow along the courses of what were once cañons, but which have become filled up by deposits. The banks are of sandy loam and average from 5 to 6 feet in height in the upper course, but not more than 4 feet toward the mouth.

The river is bordered by bottom-land, which, in the vicinity of Greeley, is in places 3 miles wide, while in others the bluffs close in and form narrows. At Denver the Platte is 150 to 200 feet wide and 4 feet deep in ordinary low water; at mean high water it runs much more rapidly than before, with a width of 500 to 800 feet, and a depth of 7 feet. Below Denver it widens out, its channel becomes very changeable, and sand-bars are frequent. Above the mouth of the Poudre the high-water width is about 700 feet and the depth 6 feet; the river widens greatly to the eastward, and in its lower course averages little less than half a mile across, with a depth, at medium stage, of 12 to 18 inches.

The volume of flow shows large fluctuations if an entire year is considered, but from month to month is comparatively steady; the river rises from May or June to July, and then falls steadily till September, after which

it remains at a low stage till the succeeding spring. To the eastward from Greeley, and thence to the mouth, it rapidly subsides after the June rise, soon disappears in its sandy bed, and apparently dries up; there is, however, a sluggish current of water percolating through the sand. The river continues dry till late in the fall. I was informed at North Platte, near the mouth, that the constantly extending use of the Platte for irrigation in Colorado during the past few years has had a marked effect on the volume in its lower course, causing the river to run dry earlier, and for a longer period, than formerly.

Although the stream runs with full banks during the June rise, it never overflows them. There is no other regularly-recurring freshet, but sudden and brief rises are liable to occur during the period of summer rains. Some years ago there was a "cloud-burst" on the upper river, which caused great damage at Denver; at that time a large volume of water came down the South Platte, and at its mouth presented a front like a wave several feet in height, and gave out a dull roaring sound which could be heard at a considerable distance. The South Platte is free from ice-gorges. No timber is found along its course below the mountains, except occasional slight fringes of cottonwood. The surrounding country is an open rolling prairie.

After issuing from the mountains, near Platte cañon, the river is repeatedly and largely drawn upon for the wants of irrigation. Near the close of 1880 an English company, having its principal office at Denver, was engaged in constructing an irrigating-canal running from the mouth of Platte cañon, 150 miles long, 40 feet wide at the bottom, and 7 feet deep; this canal was designed to irrigate 50,000 acres of land at the start, and when developed to its full capacity, 150,000 acres. (*a*) The dam at the entrance to this canal is 150 feet long, 12 feet high, and cost about $6,000; it is a framed structure, consisting of bents 12 feet high placed at intervals of 8 feet across the stream; these are timbered over and the open spaces filled in with rock.

In the vicinity of Denver no less than eight irrigating-canals run from the Platte. They usually have rude, cheap dams of brush or bowlders at the head, intended merely to divert a sufficient supply of water into the canals. The use of the Platte in this manner continues all the way from Denver to Greeley, and even extends 70 miles east of the latter place to South Platte and Buffalo. From Denver to Greeley the land along the river is, when irrigated, very valuable for small grains, corn, when the season is not too dry, and potatoes. East of Greeley the bottom-land is good when irrigated, but the bluffs are said to become too sandy to be of value.

At Greeley a flouring-mill of four or five runs is operated by water-power from an irrigating-canal, and I think there are a few small powers similarly located on canals in the vicinity of Denver. I was informed, however, that at only one point had a dam been constructed across the Platte for the purpose of obtaining power, and that was a short distance above Denver. This dam rests upon bed rock, and is partly of stone and partly of brush; it was built in 1879, and cost about $3,000. The portion consisting of stone is 150 feet long, 6 feet high, 4 feet wide at the base, and 1½ feet wide at the top; the part built of brush is 250 feet long, with a height diminishing from 6 feet to zero. The canal running from the dam is about 11,600 feet long, 30 feet wide at the bottom, 8 feet deep, and falls 1 foot to the mile. The pond above the dam contains only a few acres, but there is another of 40 or 50 acres on the line of the canal.

The canal empties into a large well, from which the greater part of the water runs onto two 54-inch turbine wheels, the remainder passing through a filtering-crib into the service-pipe, by which it is conveyed for the supply of the city of Denver. The wheels run under a head of 30 feet, and have a capacity for pumping 6,000,000 gallons a day. Their total horse-power is 600, of which about 300 is commonly used by the water-works and 75 is leased to a flouring-mill. There is sufficient water for running these establishments at full capacity nine months in the year, and one-half capacity the remainder of the time.

TRIBUTARIES OF THE SOUTH PLATTE.—Ascending the river from the mouth to Greeley, we meet successively Lodge Pole, Horse Tail, Pawnee, Beaver, Bijou, Kiowa, Box Elder, Crow, and Lone Tree creeks. They are all of the same general character, and are practically valueless for power. They contribute very little water to the Platte; rising in the open country, where the precipitation is slight, they receive but small assistance from melting snow; they run over quicksand beds, into which they sink, going dry most of the year, and it is only after heavy rains that they contain any water worth mentioning.

Above Greeley, some of the streams coming from the west, and having their sources in the mountains, are of importance, and will be described in detail. Of the lesser tributaries, Sand creek is unimportant; Cherry creek is unreliable; it runs dry in summer, but is used for early irrigation. Bear creek is small, but is used for irrigation; Twin creek is small and unimportant; Plum creek runs dry in summer and is of no consequence. Tarryall creek runs parallel to the Middle Fork of the South Platte, and about 15 miles to the northward. It runs through the mountains, is one of the large branches, and, if favorable locations could be found for mills, would carry moderate powers, and, with sufficient head, even tolerably large ones. None of the streams which I have mentioned are employed for power except Twin creek, which has a small saw-mill.

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a To Mr. E. S. Nettleton, chief engineer in this and other enterprises of the Colorado Mortgage and Investment Company, I am indebted for much information regarding the upper Platte river.

The Cache la Poudre river.—This stream rises in Larimer county, Colorado, in the mountains to the east of North Park; it takes a southeasterly course, and empties into the South Platte a few miles east of Greeley. It has a length by general course of 70 to 80 miles, about half of which lies in the mountains, from which it issues some 8 miles to the west of Fort Collins. During its run through the mountains it passes, now through narrow cañons with almost vertical walls, and again through more open valleys half a mile or a mile wide and containing fertile ground. The mountains are thickly covered with white pine timber, and some spruce and quaking ash. The pine trees are not of large diameter, but they are long and straight and afford a fine quality of lumber, not, however, considered equal to that from Michigan. After leaving the mountains the river flows through a rolling country, which, when irrigated, is suited to the raising of wheat, rye, oats, and which in about every alternate year yields a good crop of corn.

The valley of the Cache la Poudre is noted for its fertility and its value for stock-raising. It is crossed, a short distance east of the mountains, and again near the mouth, by north-and-south railroad lines (branches of the Union Pacific), and a survey has been made for a line to follow up the stream through the mountains, passing thence over into North Park. The only towns of importance on the river are Greeley and Fort Collins, each with about 1,300 inhabitants.

Near Fort Collins the river banks are now and then bluffy, but usually have a height of 5 feet, which increases as the mountains are approached. The bed of the stream is composed of bowlders; these are of large size in the mountains, but grow steadily smaller down stream, till, near the mouth, they are reduced to mere pebbles. The current is very swift; for 8 miles above Fort Collins the average fall is said to be 25 feet per mile, and from Fort Collins to Greeley 15 feet per mile. At the former point the stream is 40 to 50 feet wide in an ordinary low stage, and 4 to 6 inches deep; at mean high water it is 100 feet wide and 5 feet deep. Thence to Greeley the average width in mean high water is about 125 feet, and the depth the same as last given.

From the middle of May to the first of July melting snow and rain cause a period of high water, during which the river runs with a swollen, swift, and muddy current, not safely fordable at any point. After that time it rapidly sinks away, its subsidence being hastened by the withdrawal of large amounts of water for irrigation. It reaches its lowest pitch late in the fall, and remains very low all winter. Besides the regular spring-summer high water, there are some sudden rises which cannot be anticipated. During the period of melting snow a heavy rain will cause a rapid rise of a foot or more at Fort Collins, and such a rise may, indeed, result from a rain alone, unassisted by melting snow. Those exceedingly heavy rains termed "cloud-bursts" sometimes occur on the course of the Poudre. In the period of melting snow the sun beats down very hot during the day, while the nights are cold; consequently, the snow wastes away rapidly during the day, while the action is entirely checked at night, and the river shows sensible, daily fluctuations in volume.

Near its headwaters the Poudre drains Chambers lake, containing perhaps 1½ square miles, and also receives the drainage from some other small lakes. The facilities for storage in reservoirs are said to be very good, and the subject of such improvement has been considerably discussed. There are many natural basins in the open country near the foot-hills of the mountains, and it is considered that large amounts of water might be stored in them at reasonable expense. Already some of them have been improved as storage reservoirs to supply irrigating-canals.

Anchor ice is said to form in the mountains, clinging to the bowlders on the bed of the stream and somewhat obstructing its flow, but the mills at Fort Collins experience no difficulty with ice. There are two flouring-mills at that point, each carrying four runs of stone, and supplied with water through canals each more than a mile long; one has 11 feet head, and the other 23 feet. These mills have sufficient water for running at full capacity the year round, though in some seasons there is not much surplus. I was unable to learn of any other use of water-power from this river. At favorable points in the mountains it might doubtless be employed to good advantage, but in the open country there is but little water left after the wants of irrigation have been met. It is also a disadvantage to use for important powers that the volume shows great fluctuations during the year. During the great "Denver flood" of 1864 the Poudre ran 2 miles wide at Fort Collins.

This river is used to such an extent for irrigation that it may be of interest to explain briefly the manner in which it is put to service. The irrigation systems are commonly constructed by joint stock companies, or associations composed of the owners of land benefited. The law is said to give the preference to irrigating-ditches over mill privileges. Large main canals are run off from the stream at a slight grade, the common velocity of the water in them being about 4 feet per second; they ordinarily cost not far from $1,000 per mile, and are sometimes of great length, following the contours of the hills in very sinuous lines. Near their entrances low cheap dams are thrown across the river; these dams are commonly very rudely constructed of brush or bowlders, and are not tight, but are designed simply to divert sufficient water for supplying the main canals. The latter are tapped at frequent intervals, and through wooden sluices water is drawn off into small ditches or feeders, which run off down the hillsides with gradual slope.

A large share of the water is absorbed into the ground, a portion is directly evaporated, and some of that which leaches through the soil ultimately finds its way back into the river again. Irrigation begins in May, and, so far as the crops are concerned, does not need to be continued more than two months; but the water is a convenience

for stock, and it is customary to leave the ditches open, thus withdrawing a large amount of water at a time when the stream most needs it. The supply of water for the year 1880 scarcely sufficed for irrigation, but it is said that with proper management it can, and will, be made to do much greater service.

The highest point at which much water is taken for irrigation from the Poudre, is about 4 miles above Fort Collins, though I understand that it is used to a small extent nearly to the foot-hills of the mountains. No less than ten canals, ranging from 15 to 30 feet in width at the bottom, and numbers of smaller ones, convey water from the river. The most important one was constructed by an English company, and is known as the Larimer and Weld canal. It branches from the Poudre just above Fort Collins, and is carried easterly across Box Elder and Lone Tree creeks nearly to Crow creek. At the close of 1880 it had been completed for a length of 50 miles, and surveyed for 20 miles farther. The width of the canal at the bottom is 30 feet. Along its course are three lakes or storage reservoirs, containing from 80 to 95 acres each.

Another canal at Fort Collins is 15 feet wide and 11 miles long; and one 10 miles below the town is 25 feet wide and 20 miles long. The main irrigating-canals, being carried along the hillsides, must offer many opportunities for the use of water-power. There are a few instances in Colorado where small powers have been thus developed, and are employed by flouring-mills, but the question of putting the canals to use in this manner has not, I believe, arisen in any cases of importance. I was informed by good authority that probably the establishment of mills to a moderate extent would be permitted along the lines of large canals, provided they were so located that after using the water it might be still further employed in irrigation.

Big Thompson creek.—This is the next tributary of the South Platte above the Cache la Poudre. It runs easterly across the southern part of Larimer county, and empties 6 miles southwest of Greeley. It is about 50 miles long by general course, and has a drainage area of 862 square miles. Its principal tributary is the Little Thompson, which joins it a few miles above the mouth. There are no towns of any importance on the stream, and it has no railroad facilities except those afforded by the Colorado Central line, which follows a north-and-south direction, crossing the main stream at Loveland, and the Little Thompson at Berthoud.

The Thompson is said to be of more even flow than the Poudre, although its volume is not so large as that of the latter; it is used for irrigation, and has one flouring-mill of moderate size a mile below Loveland. Eight miles above Loveland it issues from a cañon in the mountains; its actual length from the mouth of the cañon to its source is 55 miles, in which distance there is a fall of 5,000 feet, or an average of 90.9 feet per mile. From the mouth of the cañon to Loveland, 8 miles, the fall is 500 feet, or 62.5 feet per mile; at Loveland the fall is 17 feet per mile. (*a*)

According to the arrangements in force at the beginning of 1881, of the flow of the stream 2,500 cubic feet per minute was appropriated to manufacturing; the amount appropriated to irrigation was 75 per cent. of the full flow at high water. Measurements of the volume made at a point above the mill-race near Loveland have shown a high-water discharge of about 1,200 cubic feet per second, and a discharge in autumn low water of 125 cubic feet per second. The drainage area above this locality being 509 square miles, the high-water discharge is at the rate of 2.36 cubic feet per second per square mile; that at low water is at the rate of 0.25 cubic foot per second per square mile.

Boulder creek.—This stream heads among the mountains in the southwestern part of Boulder county, Colorado; it flows to the northeast, and, about 10 miles above the point where it enters the South Platte, receives from the north Saint Vrain creek, its principal tributary. Boulder creek has a length of nearly 50 miles by general course, and a drainage area of 936 square miles. It is crossed at the town of Boulder, close to the mountains, by the Colorado Central railroad, running from Denver to Cheyenne, and is followed for 10 miles below Boulder by the Boulder Valley railroad. The principal towns are Boulder, on the main stream, population about 3,100, and Longmont, on Saint Vrain creek, population, 800.

The upper course of the stream lies in the mountains, which are thickly timbered with pine and spruce, and contain gold, silver, and other minerals. Its valley consists of a succession of deep and narrow cañons, with occasional intervals in which it widens out somewhat. The bed is of solid rock in the narrow places, but is covered with bowlders where the stream widens. From the mouth of the cañon to the head of the creek, the distance is 21 miles in a straight line, and probably 30 to 35 miles by actual course. The cañon proper is 13 miles long, in which distance there is a fall of 2,600 feet, or an average of 200 feet per mile; the greatest fall in any one mile is 470 feet, and the least is 96 feet.

A short distance above the mouth of the cañon the stream is tapped, and water is conveyed through an iron pipe to a reservoir for the supply of Boulder. Near its exit from the mountains the creek has a mean low-water width of 50 feet, and a depth of about 8 inches; at mean high water it is perhaps 60 feet wide and 2 feet deep. Below the mountains the fall continues rapid for some distance, and the Boulder Valley railroad, which follows its

a I am indebted to Mr. H. P. Handy, civil engineer, of Loveland, for most of my data concerning this stream.

course, has a grade of about 60 feet to the mile. The banks are of loam, and average 5 feet in height. Large drafts are made upon the volume to meet the demands of irrigation; within 2 miles of the mouth of the cañon there runs from the stream one canal 10 miles long, another of 2 miles, and another of 30 miles, all of large cross-section, and there are others farther down stream.

SOUTH BOULDER CAÑON.

Boulder creek has a comparatively steady flow, being well sustained through a considerable part of the year by the snows in the deep mountain valleys, which are gradually melted away by the sun. There is no danger from ice or from freshets, and a severe flood is unknown. It is thought that a considerable storage capacity might be developed at moderate expense. Numerous small lakes are said to be drained in the upper waters, though there are none of important size.

In the mountains the valley widens out at points sufficiently to accommodate mills, and though the low-water volume is not large, the narrow course, rocky bed, and rapid fall are all favorable to the development of power. The principal objection, however, to this section is its difficulty of access. Below the mountains so much of the water is used for irrigation that little is left in a low stage for any other employment. The only power in use on the stream is at Boulder, but a short distance from the cañon; here are met, successively, in descending the creek, a flouring-mill of five runs, with 30 feet head and 75 horse-power; reduction-works, using 18 feet head and 80 horse-power, with sufficient water at all seasons; a small planing-mill; and, lastly, a flouring-mill of five runs, with 23 feet head, supplied with 60 horse-power by water, and carrying an engine of equal capacity.

Clear creek.—Clear creek rises in the mountains 35 to 45 miles west of Denver, whence it flows easterly to the South Platte. It is about 50 miles long, by general course, to the source of the South Fork, and has a drainage area of 623 square miles. Near Golden it emerges from the mountains, and for the short remaining portion of its course runs through an open, rolling district, which it serves to irrigate. The principal towns are Golden, on the main stream; Central City and Black Hawk, on the North Fork; and Georgetown, on the South Fork. A narrow-gauge railroad runs from Denver up the valley of the stream to Central City and Georgetown.

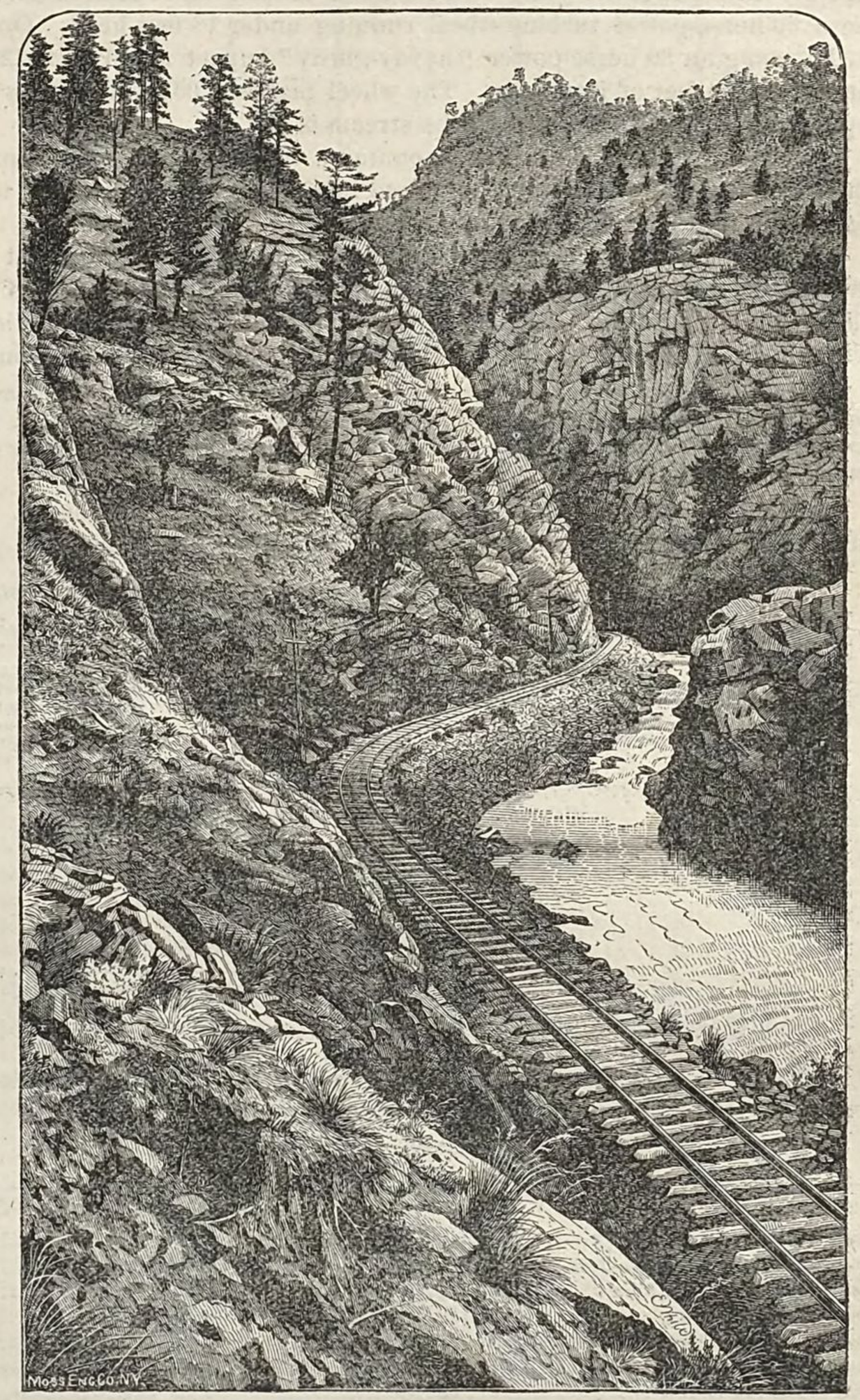
Above the point where it issues from the mountains the course of Clear creek lies through a cañon of remarkable wildness and grandeur. The stream is narrow, commonly ranging from 20 to 50 or 75 feet in width; from either side there rise, with steep and sometimes almost vertical faces, the rocky walls of the narrow valley, hardly leaving room beside the stream for the railroad which runs along its bank. The abrupt slopes rise to heights varying from 1,000 to 2,500 feet; they show but a moderate growth of timber, and their bold outlines and scarred, weather-beaten surfaces render them at once grand and forbidding in appearance. Occasionally the valley widens a little and its sides have an easier slope. On the main stream and on the North Fork the bed consists principally of small bowlders and coarse gravel. The descent is rapid, but there are no abrupt falls of any importance. In times past the bed of North Clear creek has been worked over and over in attempts to find gold, and at frequent intervals there are still to be seen the ruins of old sluices and vertical water-wheels which furnished the miners with small powers.

Ascending South Clear creek from its junction with the North Fork, its course for about 9 miles is in a narrow cañon, shut in by high, vertical walls. The bed is of coarse gravel and bowlders, some of the latter being of great size. At Idaho Springs and above the valley is wider, and now and then there is encountered an open, comparatively level spot, one-half to three-quarters of a mile in width, where the stream has but little fall.

The slope of South Clear creek varies from 40 to 101 feet per mile. On the North Fork and main stream there is a descent of 2,100 feet in the 21 miles from Black Hawk to Golden, or an average of 100 feet per mile, with a range from 49 to 180 feet to the mile. At Golden the fall is 49 to 55 feet per mile. I was informed by Captain E. L. Berthoud, of Golden, who has had an extensive engineering experience in this section, that very accurate levels, run between Golden and Forks Creek (junction North and South Forks), a distance of 13 miles by the stream, showed a rise at the latter point of seven-tenths of a foot between the years 1865 and 1872, thus indicating that the process of elevation was still going on in the mountain mass. A further rise was observed up to Central City, but the levels were not so accurately taken as on the lower section, and the result was not, therefore, so reliable.

At Golden and in the vicinity four irrigating-canals make heavy demands upon the stream, and below that locality it has no value for power. Aside from agriculture, which is confined to the section east of the mountains, the principal industries of Clear Creek valley may be said to be concentrated at Golden, Central City, and Georgetown, and those are the only points where water-power of any consequence is in use.

Golden is an important manufacturing place, and has fine advantages. It lies at the outlet of the mountain valley, through which comes the product of many valuable mines, yielding large amounts of lead and copper, as well as gold and silver. Deposits of iron ore, lignite, coal, and brick clay are found near at hand. Water is taken from the creek in races, or ditches, as they are called, one of which supplies a small paper-mill and a flouring-mill of four runs; the latter mill has 19 feet head and uses 65 horse-power. Another ditch carries water to a three-run flouring-mill, with 14 feet head and 40 horse-power. There is still another flouring-mill, which was not in operation at the time of my visit. Four smelting and reduction works also take water at this point from Clear creek, though they do not employ it for power.



ROCKY POINT, CLEAR CREEK CAÑON.

Central City and Black Hawk, which are continuous and form practically one and the same town, lie in a deep valley high up among the mountains, and nearly or quite 8,000 feet above sea-level; their chief industry is gold mining. Dwelling-houses and other buildings are scattered for some distance up the sides of the valley, while along the bottom courses the little stream called North Clear creek, bordered by the stamp-mills belonging to the different mines. These mills use the stream for power and otherwise in the operations of pounding up the ore and removing the gold. On leaving them, its waters, clear and transparent at the start, have become turned to a milky hue. The dams are rude, short, and insignificant; the water is conveyed through wooden sluices to the wheels, which are overshot or breast, employed in preference to turbines as giving a slower motion and being on other accounts better suited to the style of work. The principal concerns, in order from the upper end of the valley, are as follows:

1. Wheeler and Sullivan mill; wheel 25 feet in diameter; runs 25 stamps in summer.

2. Fullerton's mill; wheel 22 feet in diameter; runs 33 stamps.

3. Arige and White's mill; breast-wheel, 12 feet in diameter; runs 10 stamps.

4. Zinzendorf mill; overshot wheel, 25 feet in diameter; runs 25 stamps.

5. Fullerton's lower mill; breast-wheel, 25 feet in diameter; runs 40 stamps in summer.

6. Kimber mill; breast-wheel, 22 feet in diameter; can run 35 stamps in summer.

7. Bobtail mill; breast-wheel, running under 21 feet head, and estimated at 40 horse-power; has enough water to run at full capacity five months in the year, but steam is used the remainder of the time; 40 stamps, I believe, are run.

8. New York mill; breast-wheel, 33 feet in diameter and 5 feet wide; 25 horse-power obtained eight months in the year, and 50 horse-power four months.

9. French's mill; overshot wheel, 25 feet in diameter and 5 feet wide; in summer can run 35 stamps, each weighing 600 pounds, and making 28 strokes per minute.

Georgetown is a great silver-mining center, and lies in a deep valley, perhaps half a mile to a mile wide, shut in by the almost vertical faces of the mountains, which rise 1,500 to 2,500 feet above the stream. South Clear creek here flows through a flat, sandy piece of ground, which it overflows in high water. It divides into two small branches, on one of which power is used by the Clear Creek Company's reduction works. Power is taken from a "hurdy-gurdy" impact wheel 8½ feet in diameter and 6 inches broad; it runs under a head of 220 feet, water being brought from a point up the valley 1,440 feet in an iron pipe. The supply of water is sufficient for running at full capacity throughout the year. On the other branch G. W. Hall & Co. have a saw-mill and ore-sampling works, and use a 30 horse-power turbine wheel running under 18 feet head. On the same branch are the Farwell reduction works, using an 80 horse-power "hurdy-gurdy" impact wheel with 120 feet head; water is brought to this wheel through 1,300 feet of iron pipe. The wheel makes 1,058 revolutions per minute; it is wasteful of water, and is supplemented by a turbine when the stream is low.

In the open country near the mountains there are numerous depressions, probably dating from glacial times, which can at moderate expense be turned into storage reservoirs, and this improvement has already been effected in some cases for the purposes of irrigation.

The discharge of Clear creek has been repeatedly measured, at intervals over a period of twenty years, by Captain Berthoud, the results of whose observations are given in the table below. The measurements include the whole volume naturally belonging to the stream at Golden, undiminished by withdrawals into races or canals. With reference to rainfall Captain Berthoud divides the water-shed into two zones:

The first zone is that portion that extends along the foot-hills and in the immediate valley of Clear creek and its tributaries to Georgetown, Bakerville, Upper Empire, Black Hawk, Central and Quartz valley. The second zone includes the whole mountain range around Bergen Park, head of Beaver creek, Soda, Chicago, South and West Clear creeks above Georgetown, Bakerville, Upper Empire, Central, Nevada, and Mountain City.

In the first zone the yearly rainfall varies from 13½ to 18¾ inches. In the second zone it varies from 18¾ to 31½ inches, and for the entire area is estimated to average 20.62 inches.

Discharge of Clear creek, as measured by Captain E. L. Berthoud.

[Drainage area above Golden, 436 square miles.]

Stage of water.	Cross-sectional area in square feet.	Average velocity in feet per second for entire cross-section.	Volume in cubic feet per second.	Volume in cubic feet per second per square mile.
High water	280.23	4.27	1,197	2.75
Medium stage	121.07	3.84	465	1.07
Low water, average year	33.97	2.22	75	0.17
Low water, ordinarily dry year (approximate)	25.50	2.10	54	0.12
May 19 to August 27 (100 days), average of years *	194.82	3.24	631	1.45
August 27 to May 19 (265 days), average of years *	57.00	1.84	105	0.24

* Estimated by Captain Berthoud.

From these results it appears that the average annual discharge is about 38 per cent. of the rainfall.

Drainage areas of tributaries of the Platte, North Platte, and South Platte rivers.

Stream.	Tributary to what.	Drainage area.	Stream.	Tributary to what.	Drainage area.
		Sq. miles.			*Sq. miles.*
South Platte, below South Fork	Platte	709	Plum creek	South Platte	326
South Platte, below Tarryall creek	do	1,627	Bear creek	do	279
South Platte, below North Fork	do	2,663	Cherry creek	do	459
South Platte, at Denver	do	3,993	Clear creek	do	623
South Platte, at Greeley (below Poudre)	do	9,867	Boulder creek	do	936
South Platte, at mouth	do	24,468	Thompson creek	do	862
North Platte, at Fort Steele	do	3,950	Cache la Poudre	do	2,614
North Platte, at Fort Fetterman	do	17,150	Crow creek	do	1,546
North Platte, at Fort Laramie, including Laramie river.	do	24,090	Box Elder creek	do	675
North Platte, at mouth	do	35,574	Kiowa creek	do	797
Wood river	do	718	Bijou creek	do	1,458
Prairie creek	do	578	Beaver creek	do	1,300
Loup river	do	15,553	Pawnee creek	do	817
Shell creek	do	533	Horse Tail creek	do	484
Elkhorn river	do	6,732	Lodge Pole creek	do	3,036
Salt creek	do	1,616	Medicine Bow river	North Platte	2,432
Platte, at mouth	Missouri	90,407	Sweetwater river	do	4,037
South Fork	South Platte	430	Poison Spring creek	do	1,429
Tarryall creek	do	484	Laramie river	do	4,500
Trout creek	do	223	Raw Hide creek	do	632
North Fork	do	518	Horse creek	do	1,942

Estimated volume and horse-power of some of the tributaries of the Platte and South Platte rivers.

Stream and locality.	Approximate rainfall on drainage area.					Drainage area.	Low water, ordinarily dry year.		Low water, average year.		Available 10 months in average year.	
	Spr.	Sum.	Aut.	Wr.	Yr.		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches*	*Sq. miles.*						
Salt creek, at Newton	9	13	6	2	30	815	35	40	45	51	70	80
Salt creek, at mouth	9	13	6	2	30	1,616	70	80	85	97	140	159
Elkhorn, at Neligh	6	8	3	2	19	2,057	70	80	115	131	140	159
Elkhorn, below North Fork	6	9	3	2	20	3,378	120	136	200	227	250	284
Elkhorn, at West Point	6	9	3½	2½	21	4,309	160	182	270	307	330	375
Elkhorn, at mouth	7	9	3½	2½	22	6,732	260	295	430	488	540	613
Maple creek	7	10	5½	2½	25	477	20	23	30	34	45	51
Logan creek	7	10	5½	2½	25	1,051	40	45	80	91	100	114
Cache la Poudre at Fort Collins *	5½	6	4½	2½	18½	1,233	150	170	190	216	260	295
Big Thompson, at Loveland *	5½	6	4½	2½	18½	509	60	68	75	85	100	114
Little Thompson, at Berthoud *	5½	6	4½	2½	18½	171	20	23	25	28	35	40
Saint Vrain, at Longmont *	5½	6	4½	2½	18½	324	35	40	45	51	60	68
Boulder, at Boulder *	5½	6	4½	2½	18½	142	15	17	20	23	30	34
Clear, at Golden *	6½	6	4½	3½	20½	436	54	61	75	85	100	114

* Estimates are for natural flow, undiminished by withdrawals for irrigation.

Power utilized on Platte river and tributaries.

[Not including power used in Wyoming or in mining operations in Colorado.]

Stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Platte	Missouri	Nebraska	Polk	Flour and grist	1	8	36
Do	do	do	Merrick	do	*5	46	217
Do	do	do	Hall	do	1	8½	23
Salt	Platte	do	Saunders	do	1	7	40
Do	do	do	Lancaster	do	3	34	94
Small streams	Salt	do	Saunders	do	6	78	219
Do	do	do	Lancaster	do	4	48	123
Elkhorn	Platte	do	Douglas	do	1	6	62
Do	do	do	Washington	do	1	6	43
Do	do	do	Cuming	do	1	8	95
Do	do	do	do	Paper	1		65
Do	do	do	do	Saw	1		20
Do	do	do	Antelope	Flour and grist	1	8	66
Tributaries	Elkhorn	do	Dodge	do	4	51	212
Do	do	do	Cuming	do	1	16	24
Do	do	do	Burt	do	2	15	99
Do	do	do	Madison	do	3	36	115
Do	do	do	Antelope	do	1	16	63
Do	do	do	Holt	do	1	14	22
Shell	Platte	do	Colfax	do	3	40	221
Do	do	do	Platte	do	1	14	28
Tributaries	Loup	do	Howard	do	4	44	92
Do	do	do	Greeley	do	1	9	9
Do	do	do	Boone	do	2	21	95
Do	do	do	Buffalo	do	1	6	14
Wood	Platte	do	Hall	do	1	11	30
Do	do	do	Buffalo	do	2	25	102
Small streams	do	do	Cass	do	2	40	32
Do	do	do	Butler	do	1	12	12
South Platte	do	Colorado	Arapahoe	Water works (Denver)	1	30	600
Tributaries	South Platte	do	do	Flour and grist	7	66	505
Cache la Poudre	do	do	Larimer	do	2	34	115
Small stream	Cache la Poudre	do	do	Saw	1	20	14
Big Thompson	South Platte	do	do	Flour and grist	1	19	40
Boulder	do	do	Boulder	do	2	53	135
Saint Vrain	Boulder	do	do	do	4	101	172
Small stream	do	do	do	Saw	1	18	12
Clear creek	South Platte	do	Jefferson	do	1	16	16

Power utilized on Platte river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Clear creek	South Platte	Colorado	Jefferson	Paper	1	18	70
Do	do	do	do	Flour and grist	3	39	130
Do	do	do	Clear Creek	Saw	1	12	30
Small stream	Clear creek	do	do	do	1		25
Twin	South Platte	do	Park	do	1	16	20
SUMMARY.							
Platte	Missouri	Nebraska		Flour and grist	*7	62½	276
Salt	Platte	do		do	4	41	134
Tributaries	Salt	do		do	10	126	342
Elkhorn	Platte	do		Flour and grist (1 paper and 1 saw).	6	28	351
Tributaries	Elkhorn	do		Flour and grist	12	148	535
Shell	Platte	do		do	4	54	249
Tributaries	Loup	do		do	8	80	210
Wood	Platte	do		do	3	36	132
Small streams	do	do		do	3	52	44
South Platte	do	Colorado			1	30	600
Tributaries	South Platte	do			26	412	1,284
Total					84	1,069½	4,157

* Some of these may be on tributaries.

THE LITTLE NEMAHA RIVER.

This is a small stream rising in Otoe county in southeastern Nebraska; it pursues a southeasterly course through Otoe and Nemaha counties, and empties into the Missouri at Nemaha City. It is 60 miles long by general course, and drains an area of 990 square miles. The surrounding country is rolling, and yields well in wheat and corn. Sandstone and limestone suitable for building are found in the counties above mentioned, and a moderate amount of timber occurs along the course of the stream, consisting mainly of walnut, oak, and elm. From the mouth of the stream a branch of the Burlington and Missouri River railroad runs north along the Missouri to Nebraska City; another branch follows the upper river above Syracuse, but the intervening portion is without direct railroad facilities. Syracuse is the largest town on the river, and has about 500 inhabitants.

The river flows in a broad alluvial bottom, bounded by lines of well-rounded bluffs. The bed consists of mud to a depth of 2 or 3 feet, underlaid by clay. The banks are of loam, and 5 to 10 feet high. Toward the mouth the stream is about 150 feet wide. It does not overflow its banks seriously. The freshets to which it is subject are generally caused by the heavy rains of early summer, though they sometimes arise in spring from suddenly melting snow. The flow of the stream is said to be quite steady; toward the mouth the current is sluggish, and during high water the mills are troubled for a month or six weeks by backwater.

I have no exact elevations of the water surface of the Little Nemaha. The mouth is approximately 915 feet above sea-level, and the railroad grade at Syracuse is given as 1,064 feet above the same plane. The distance between these points is 36 miles by general course, for which the fall probably averages from 3 to 4 feet per mile.

Power is used from this river by a number of flouring- and grist-mills, which carry from one to three runs of stone each, and obtain heads of 5 to 16 feet. The dams are said to be mainly brush, and to range in length from 100 to 150 feet, and in height from 7 to 10 feet. The lowest power on the river is at Nemaha City, near the mouth, and is used by a two run flouring-mill. The dam consists of a row of piles, backed with loose stone and rubbish. The piles are 16 feet long, 15 inches in diameter, and in mid-stream are about 4 feet apart. This dam was built in 1880, and seems to answer its purpose well enough thus far, though it is not tight. It is 150 feet long, with an average height of 7 to 8 feet, and cost about $1,500.

The rainfall on the basin of this river may be taken as in spring, 9 inches; summer, 15 inches; autumn, 7 inches; winter, 2 inches; year, 33 inches. I estimate the discharge available during ten months in an ordinary year as below:

Locality.	Drainage area in square miles.	Volume, in cubic feet per second.	Theoretical horse-power, 10 feet head.
At Howard	788	90	102
At mouth	990	110	125

Power used on the Little Nemaha river.

Stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Little Nemaha	Missouri	Nebraska	Nemaha	Flour and grist	5	47	151
Do	do	do	Otoe	do	4	52	77
Total					9	99	228

THE NEMAHA RIVER.

The main Nemaha is formed by the union of its North and South Forks, in Richardson county, Nebraska, and lies some 20 miles south of the Little Nemaha. From the head of the North Fork to the mouth of the main stream the distance is 88 miles by the general course of the river. The entire drainage area of this river measures 1,924 square miles, of which 600 is in Kansas. The region thus included is a good farming district, contains an abundance of very fine limestone for building, and has some coal. Fringes of timber occur along the river and its tributaries, principally elm, black walnut, cottonwood, and box elder. The surface of the country is mainly undulating prairie, about 3 per cent. being timbered and 10 per cent. bottom-land. (*a*) A division of the Burlington and Missouri River railroad follows the Nemaha and its North Fork, from mouth to source, and then passes on to Lincoln, the capital of Nebraska. The principal towns on the river are Falls City, population 1,600, and Tecumseh, population 1,300.

The rails of the Burlington and Missouri road have an elevation of 865 feet above the sea at the crossing near the mouth, and 1,075 feet at Tecumseh. The intervening distance is by general course 55 miles, for which there is, as above, a fall of approximately 210 feet, or very nearly 4 feet per mile.

The river runs through an alluvial bottom, which ranges from half a mile to a mile and a half in width, and is flanked by gently-rounded bluffs, handsomely terraced in places. The banks of the main stream are clayey, and rise 10 to 25 feet in height above low water. The bed is muddy in that stream, but in the South Fork contains frequent ledges of limestone; in the North Fork the bed is rock, gravel, and clay. These two forks are said to be of about equal size. Near Falls City the main river averages, at low water, 75 feet in width and 2 feet in depth, but at high water it runs with full banks, probably 100 feet wide and 20 feet deep. Occasionally it overflows its banks and spreads out to a width of half a mile or a mile. The fall of snow in this section is not commonly sufficient to cause a heavy freshet, and the extraordinary size noted above results from the heavy rains of early summer. The ordinary rise in the lower river is about 15 feet.

The Nemaha has quite a steady flow from month to month; its current is sluggish in low stages, but in high water it is a rapid stream. The mills experience no trouble with ice. The North and South Forks are each about 40 feet wide. Both upon them and upon the main river water-power is used by numerous flouring-mills. The dams are said to be usually of brush, costing $700 to $800 each. They are, on the average, perhaps 80 feet long and 8 to 15 feet high. The ponds formed are mainly confined within the natural banks of the river. At Falls City, on the main stream, a privilege is occupied by the Falls flouring-mill, carrying three runs of stone. The river had a natural fall at this point of 4 feet over a ledge of blue limestone. The dam is simply a stone wall, 5 feet high, 18 inches thick, and 100 feet long, backed by a mass of brush, loose rock, and earth. It would now require probably $1,000, according to the owner's estimate, to replace it; it was built in 1857, and is reported to have stood well; the annual cost for repairs is about $100. The wheel furnishes 40 horse-power under a head of 10 feet. There is an abundance of water for running day and night at all seasons.

Estimated volume and horse-power of the Nemaha river.

[Available ten months in an average year.]

Locality.	Drainage area in square miles.	Volume, in cubic feet per second.	Theoretical horse-power, 10 feet head.
North Branch, at Tecumseh	306	35	40
North Branch, at mouth	605	70	80
South Branch, at mouth	770	90	102
Main stream, at junction North and South Branches	1,375	150	170
Main stream, at mouth	1,924	210	239

a These are the returns for Nemaha county, Kansas, but probably are not far out of the way for the rest of the basin.

Power used on the Nemaha river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Nemaha	Missouri	Nebraska	Johnson	Flour and grist	3	35	69
Do	do	do	Pawnee	do	2	24	70
Do	do	do	Richardson	do	6	56½	224
					11	115½	363
Muddy creek	Great Nemaha	do	do	do	2	22	51
Walnut creek	do	Kansas	Brown	do	1	13	50
Total					14	150½	464

THE KANSAS RIVER.

The next great river south of the Platte is the Kansas, or, as it was called by the Indians, Kaw; and, like the former stream, it receives the drainage of a large tract of those vast prairies which are spread out to the west of the Missouri. The Kansas river, as such, is comparatively a short stream, being formed at Fort Riley, in Davis county, Kansas, by the union of the Republican and Smoky Hill; but through those rivers and its other tributaries it reaches out over a wide region, and the entire system is very extensive, embracing in its drainage basin 59,750 square miles, of which 8,420 lies in Colorado, 16,430 in Nebraska, and 34,900 in Kansas.

The area thus included has an extreme length from east to west of 485 miles; it is 190 miles wide in the broadest part, and has an average width of not far from 140 miles. The country presents, throughout, essentially the same general appearance, so far as the contour of its surface is concerned; it is a rolling prairie, through which meander the streams in winding courses, running through broad and fertile bottoms flanked on either side by bluffs. In the eastern part of Kansas the rivers are fringed with groves of timber, but as we advance to the westward this becomes more and more scant, and practically disappears at the ninety-ninth meridian. The soil is very fertile, and produces large crops of corn, wheat, and other grains. West of the limit above mentioned, however, the rainfall is unreliable, and failures of crops are common. The soil continues of natural richness over the greater part of the state, but toward the Colorado boundary it grows light and sandy, and is said to have but little value.

To come more directly to the main river, it must be noted that the country bordering its course is a well-settled farming section, and contributes to the growth of numerous thriving towns and cities. Kansas City, which is at the mouth, on the Missouri river, has a population of about 56,000. Following up the stream, the more important places are Lawrence, 8,500 inhabitants; Topeka, 15,500; Saint Mary's, 900; Wamego, 1,800; Manhattan, 2,100; and Junction City, at its head, 2,700. Good building stone is abundant, and there are valuable limestone quarries at Manhattan, Lawrence, and other points. The Junction City limestone, which is largely used for building, is fine-grained, and so soft that it can be sawed and planed with the ordinary tools of a carpenter. It hardens on exposure, is very durable, and has been successfully used for bridge-piers.

The Kansas river flows through a rich alluvial bottom, and has considerable timber bordering its lower course. In the neighborhood of Saint George, some 6 miles below Wamego, and again at Rocky Ford, 18 miles above Topeka, the river bed contains rock and bowlders, but in general it is composed of sand, and frequently of quicksand. Mr. J. B. Whitaker, city engineer of Topeka, states that in that section the quicksand commonly reaches a depth of 6 to 8 feet. At that depth there is encountered a compact layer, 2 to 4 feet thick, of fine sediment. It is very elastic, and when piles are driven upon it they at first rebound, as though from rock, but penetrate with successive blows. Below this layer quicksand is again encountered. The banks are sandy, and easily cave in; one bank is usually higher than the other, rising about 25 feet above low water, while the lower one has a height of only 10 or 12 feet. The channel generally hugs one bank or the other, and is somewhat shifting. Islands are formed here and there by the deposit of sediment during high water. Drift lodges upon them, and there soon springs up a thick growth of brush, mainly cottonwood.

At Topeka the river is 900 feet wide between banks. At ordinary low water the channel occupies 150 to 200 feet of this width, having a depth of 8 to 9 feet; over the remaining width the depth is only 1½ to 2 feet. At mean high water the stream probably averages 10 feet in depth for the entire distance between banks. As with the other streams of this section which have been described, so with the Kansas, highest water usually occurs in June or July, the season of heavy rains. An important rise may occur at other seasons, and sometimes results from melting snow in spring, but in the upper basin the snowfall is light, and since the river does not reach to the mountains it can receive no accessions from that source, as does the Platte. Up to the year 1881 it had only been known to

overflow extensively once in twenty-five years. In 1844 there was a famous freshet, when the river rose 30 feet and flooded the bottoms. Again, in 1858 it rose 24 feet, but in ordinary years the extreme range between high and low water is only 14 to 16 feet. Local storms sometimes occur in the valleys of the tributaries of such violence that those streams pour large volumes of water into the main river and cause, temporarily, an up-stream current in the latter above their mouths. In ordinary years there is not a heavy run of either ice or drift in this river.

The Kansas River valley has good railroad facilities. The Kansas Pacific road, from Kansas City to Denver, runs along its north bank; it is skirted on the south side, from Topeka to the mouth, by the Atchison, Topeka and Santa Fé, and is also crossed by north-and-south lines. The subject of improving the river for navigation has been considered, and, under the direction of Major Suter, an examination was made in 1878, with reference to that object. From the report of that examination it appears that as early as 1855 boats plied between Topeka and the Missouri, and now and then found their way as far west as Fort Riley, 185 miles from the mouth. At present, however, the river is not navigable. From Junction City to Topeka, about 100 miles, the least low-water depth is 12 inches, and thence to the mouth, say 90 miles, it is not less than 2 feet. The chief natural obstructions are shifting sand-bars, snags, and occasionally rocks; navigation is also artificially hindered by a dam at Lawrence, and by ten bridges, located at various points, and all unprovided with draws.

A rough estimate gave $450,000 as the total cost of improving the river so as to insure a channel depth of 4½ feet from the mouth to Topeka, and 3½ feet above that point. The proposed plan of improvement was to clear away snags and rocks, and to contract the water-way by the construction of dikes of brush and stone. The above estimate did not provide for a canal around the Lawrence dam, or for the introduction of draws into the bridges. No work has been undertaken upon the river thus far.

Slope of the Kansas river (water surface).

Locality.	Elevation above sea-level.	Distance between points.	Fall between points.	Fall between points.
	Feet.	*Miles.*	*Feet.*	*Ft. per mile.*
Mouth of Republican river	1,070.66			
		24.00	46.5	1.92
Manhattan	1,024.16			
		13.50	19.31	1.43
Saint George	1,004.85			
		10.25	17.5	1.71
Wamego	987.35			
		14.00	34.0	2.43
Saint Mary's	953.35			
		32.50	61.2	1.88
Topeka	892.15			
		37.25	67.8	1.82
Lawrence, above dam	824.35			
		.....	9.1	.....
Lawrence, below dam	815.25			
		30.50	41.5	1.36
Tiblow	773.75			
		22.00	33.75	1.65
Union Pacific railway bridge, 1½ miles from mouth of river.	740.00			

NOTE.—The items of fall between points are as contained in the government engineer's report, already referred to. The elevations above sea-level are obtained by adding these figures to the level of water surface (740 feet) near the mouth of the river, as given by Union Pacific railway profiles. The resulting elevation at the head of the river is 2.66 feet greater than as given independently by Union Pacific railway profiles.

Above Manhattan the width of the river ranges from 200 to 600 feet; between Wamego and Saint Mary's it reaches 900 feet in places. The flow of this stream is said to be quite uniform from month to month, but scarcely any measurements have been made of its actual volume. In 1878, during the examination of the stream by government engineers, a measurement was made between Wamego and Saint Mary's, at a stage about four-tenths of a foot above low water. The volume was found to be 2,500 cubic feet per second, which, for the 55,500 square miles of drainage area above Saint Mary's, corresponds to about 0.045 cubic foot per second per square mile. During the winter of 1874–'75, in an unprecedented drought, the discharge is stated to have been 2,000 cubic feet per second at Topeka. The drainage area above that city being 56,354 square miles, the above figures indicate a flow at the rate of 0.035 cubic foot per second to the square mile.

POWER AT LAWRENCE.—The only point at which water-power is used on the Kansas river is at Lawrence, in Douglas county. At an early day it was considered an available site, and various surveys were made with a view to developing it. The river is there about 600 feet wide, with banks of only moderate height on the north side, while on the south side, on which the city is located, they rise quite abruptly 50 feet or more from the water. A road bridge spans the river immediately above the dam. The Atchison, Topeka and Santa Fé railroad runs along the south bank, and on the north side of the river is the Kansas Pacific line.

The original dam was built in 1872, of logs and brush, after the usual style of brush dams. It rested directly upon sand, however, and in 1874, during a heavy flood, water worked under it, washed away the sand, and carried off 300 feet of the dam. In 1877 the remaining 300 feet was carried away in the same manner. The damage in each case was perhaps $5,000. The scour at the times of these accidents swept away the sandy bed upon which the

old structure had rested, and left a firm foundation for the present one. This new dam was built as the old one gave way; consequently 300 feet of it was constructed in 1874, and 300 feet in 1877. It has a total length of 600 feet, with an average height of 8 feet. The cost of the entire work, including dam and race-way, is roughly estimated at $100,000.

One-half the length of the dam rests upon a rock ledge and one-half upon hard-pan. That portion upon rock is built of large stones laid in cement, is 20 feet wide at the base and 6 feet at the top, sloping both ways. The remainder of the dam is a framed superstructure, resting on cribs filled with stone. These cribs are 50 feet long, and are laid with the stream; they project below the dam, and are planked over so as to form an apron. The crib-work foundation extends from the river bed up to about the level of low water. Above the dam the bed is covered to a distance of 40 feet with loose rock; below the dam the river banks are protected by rip-rap. On the south side of the stream the dam abuts upon the heavy masonry wall of the race-way, and upon the opposite side upon a timber crib filled with stone. The bulkhead at the entrance to the race is protected from ice and drift by a short wing-dam of crib-work. In February, 1881, the river was visited, for forty-eight hours, by a heavy run of ice 15 inches thick, which carried away from the south end of the dam two courses in depth of stone for a length of 200 feet from the shore.

The dam causes slack water for some 6 miles up stream, thus furnishing storage over a surface of 300 to 400 acres, with an average depth estimated at 6 to 8 feet. The race-way is 60 feet wide, and inclosed by heavy masonry walls 18 feet high. It is estimated to carry sufficient water for 500 horse-power. Eight Leffel wheels, ranging from 40 to 74 inches in diameter, are run, under a head of 8 to 9 feet. The only concern taking power directly from the wheels is the Douglas County flouring-mill, power being transferred to the other establishments by the use of wire cables. The loss of power is not considered to be serious, and the system works well. The mills operated by this means are located upon both sides of the river, and at considerable distances from its banks; the longest distance to which power is conveyed is half a mile. Power is supplied to four flouring-mills and two elevators, a foundry and machine-shop, a woolen-mill, a shirt-factory, a hay-press, and a concern for the manufacture of wire fencing, the last five being small establishments. Altogether 250 to 300 horse-power is used. The mills are troubled by backwater about one week in the year.

The Lawrence water-power is now owned by Mr. J. D. Bowersock, of that city. The rate charged for water is $20 a year per horse-power, the latter not measured, but estimated approximately. There is opportunity for the use of a large additional power on each side of the river, and I was informed by Mr. Bowersock that land for mill-sites would probably be given outright to induce the establishment of new concerns. The location is claimed to be valuable for factories to engage in the manufacture of cotton and woolen goods, furniture, paper, boots and shoes, agricultural implements, and oil. Wool is raised in every direction, the adjoining counties produce large crops of castor-oil beans and flax, and it is even stated that cotton may be successfully grown in Kansas.

The Lawrence privilege is claimed to have a capacity, at minimum stage of water, of 1,500 effective horse-power, which appears to be a reasonable estimate, although, in the manner in which the power is improved, and with the use of long cables, it could not all be realized in practice. I estimate the theoretical power as follows:

Estimate of power at Lawrence, Kansas.

[Drainage area, 58,235 square miles.]

	Low water of ordinarily dry year.	Low water of average year.	Available 10 months in average year.
Volume in cubic feet per second	2,200	2,550	3,100
Theoretical horse-power, 1 foot head	249.92	289.68	352.16
Theoretical horse-power, 9 feet head	2,250	2,610	3,170

This estimate assumes the power to be in use day and night; if it be employed but twelve hours daily it may be substantially increased by the large storage above the dam.

UNDEVELOPED POWER NEAR TOPEKA.—From what has been said concerning this river, it may be seen that the chief natural hinderances to its development for power are its width, slight fall, and the sandy nature of its bed and banks, bringing expense and danger in the construction and maintenance of dams. It carries a good deal of sediment, and is visited by occasional heavy runs of ice. There is also a lack of sufficient capital in this section for such enterprises as the development of extensive water-powers. Though the only dam on the river is at Lawrence, the construction of one in the vicinity of Topeka has been considerably discussed. Eighteen miles above the city rapids extend for 200 feet, with a fall of 1.25 foot in that distance; for the 2,700 feet below there is a total fall of 1 foot, or, in all, 2.25 feet in 2,900 feet. The bed of the river is rocky at these shoals, though the engineer's report, previously referred to, speaks of the rocks as appearing to be loose and capable of removal.

Three miles above Topeka there is another location, which is considered suitable for a dam. An article concerning this site says:

The width of the river at that point is 700 feet, the height of the banks such as to allow of the erection of a dam 12 feet in height. The rock bottom which extends across the river is of varying depth, being 2 feet below low water at the south side of the river, and 23 feet at the north side. The rock, with the exception of 50 feet in width on the south side of the river, is covered with sand. The race-way will be built on the south side of the river, and will run along the foot of the bluff, on the chord of which the river is the arc. The length of the race-way will be about 2½ miles, of which distance nine-tenths of a mile will be in the bed of an old wet-weather creek; which, in places, is 30 feet in width, and of a depth far below the bottom of the race-way. The ground between the site of the proposed race-way and the river has, for the most part, an elevation of several feet above high water in the river. The rock on the south side of the river will afford excellent foundations for the south abutment and the head-gates of the race-way.

I should estimate the volume and gross power at this privilege as follows, reckoning upon the constant flow of the stream:

Estimate of power at proposed site near Topeka.

[Drainage area, 56,354 square miles.]

	Low water, ordinarily dry year.	Low water, average year.	Available ten months in average year.
Volume, cubic feet per second	2,100	2,450	3,000
Theoretical horse-power, per foot fall	238.56	278.32	340.80

TRIBUTARIES OF THE KANSAS RIVER.

In describing the tributary streams I shall consider them in order above the mouth of the main river.

The first stream to be noticed is Big Stranger creek, which flows from the north, draining portions of Leavenworth, Jefferson, and Atchison counties. It is small, having a length by general course of about 50 miles, and a drainage area of 545 square miles. I was informed by Mr. D. N. Barnes, surveyor of Leavenworth county, that power is used from the stream by two small mills in that county, one of two runs in Easton township, and one of three runs near the south line of Stranger township. The dams are said to be of stone, laid in cement and backed by gravel. The mills have water enough to run them for about ten months in the year. The stream is sluggish and crooked, has high alluvial banks, a bed mostly composed of thick mud, and shows very few rock ledges. At an ordinary stage it is about 20 feet wide and 1 foot deep, but in high water it runs 200 feet wide and 25 feet deep. It is subject to sudden and heavy rise and fall. Mr. Barnes said there were three fair locations along the stream not improved.

Wakarusa creek flows into the Kansas from the south, a short distance above the Big Stranger, and lies in Douglas and Shawnee counties. It is a small stream, with a drainage basin of 520 square miles. No mills are returned as using power, but I have no further information about it.

The next tributary of consequence is the Delaware river, formerly called the Grasshopper. Its source is in Nemaha county, whence it runs to the south, emptying into the Kansas river 10 miles northwest of Lawrence. It is 70 miles long by general course, and drains 1,200 square miles. At Valley Falls, where crossed by the Atchison, Topeka and Santa Fé railroad, the water surface has an elevation of 901 feet above tide. At the Kansas Pacific crossing, near the mouth, the elevation of the water surface is 850 feet. By map measurement the intervening distance is 26 miles, for which the average fall is thus about 2 feet per mile. Almost every foot of the fall noted above is said to be utilized.

At Valley Falls the river has an ordinary width of about 100 feet. The valley is there a quarter of a mile wide, and well wooded. The river bed in this section is rocky, composed largely of limestone and soapstone, but is also gravelly in places. The banks are alluvial, and about 20 feet in height. Once in a few years the stream overflows its banks and spreads out over the valley. The highest rise was 26 feet in 1858. There has been a marked improvement in the stream in the past twenty years. That length of time ago it had little value; one small mill used it for power, but was obliged to shut down for eight months in the year. The stream was then very flashy, but is now comparatively steady, being much better supplied by springs than formerly.

Beginning at the headwaters, the mills on this stream are said to be located as follows: Muscotah, one mill; Arrington, one mill of three runs; Half Mound, one mill of three runs; Valley Falls, one mill of two runs, and one of four runs; Osawkie, one mill of three runs; and there are possibly one or two others farther down. They are said generally to have framed dams, founded upon rock beds, and to use heads of 7 to 9 feet. I was told that there was one unimproved privilege some 4 miles below Valley Falls, where the bed is soapstone. At the upper mill at Valley Falls 50 horse-power is used, with a head of 8 feet. The dam was built in 1855, at an estimated cost of perhaps $900. It is 115 feet long, 8 feet high, and is a framed structure filled and faced with stone. It rests upon a limestone bed, and abuts at one end upon a masonry wall and at the other upon a crib filled with stone. The pond sets back 5 or 6 miles up the river. At one end of the dam the power is used to run the flouring-mill and a pump

for the railroad water-tank. Power is also carried by cable 250 feet to a one-set woolen-mill, and 800 feet to a grain elevator of 15,000 bushels capacity. There is usually sufficient water to run all these throughout the year, but there is sometimes a scarcity in August and September. The proprietor of the woolen-mill informed me that he found woolen manufacturing unsatisfactory here, chiefly from the difficulty in finding good hands. He manufactures jeans, cassimeres, yarns, and flannels, the two latter articles meeting with ready sale.

The rainfall on the Delaware basin may be taken as in spring, 8 inches; summer, 13 inches; autumn, 8 inches; winter, 4 inches; and for the year, 33 inches. I assume the discharge, available ten months in an average year, and the corresponding horse-power, as below:

Estimated power of the Delaware river.

Locality.	Drainage area, in square miles.	Volume, in cubic feet per second.	Theoretical horse-power, 10 feet head.
Arrington, above Elk creek	612	75	85
Valley Falls	951	110	125
Mouth of river	1,200	140	159

THE BIG BLUE RIVER.

One of the most favorable streams for water-power that I visited in the Missouri basin is the Big Blue river. It is formed in southeastern Nebraska by a number of small forks which rise but a few miles south of the Platte river. The North and West Forks, which are the most important of these, receive several minor streams, and themselves unite a few miles above Crete, in Saline county, Nebraska. The Big Blue then continues southward into Kansas, receiving no important accessions till, just above Blue Rapids, it is joined by the Little Blue. It empties into the Kansas river at Manhattan, 160 miles from the Missouri. From the junction of the North and West Forks the distance to its mouth is, by general course, 100 miles. Its drainage basin has an extreme width of about 120 miles, at the headwaters, but narrows rapidly toward the south, and comprises an area of 9,574 square miles.

The surface of the country drained is a rolling prairie, with but little timber. It is a fine agricultural section, wheat and corn being the chief productions. There is an abundance of good building stone. The river has a railroad skirting the greater part of its course, and is crossed at several points by important east-and-west lines. Beginning at the mouth, the more prominent towns on the river are Manhattan, population 2,100; Blue Rapids, 800; Marysville, 1,200; Blue Springs, 500; Beatrice, 2,400; Wilber, 700; and Crete, 1,900.

The Big Blue has a good fall, numerous exposures of limestone in its bed, a well-sustained and steady flow, and never overflows its banks to an important extent.

Slope of the Big Blue river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Seward †	1,408			
		88	22	4.00
Crete †	1,320			
		107	28	3.82
Beatrice †	1,213			
		81	34	2.38
Marysville ‡	1,132			
		108	69	1.56
Manhattan §	1,024			

* Map measurement.
† Elevation of rails, Burlington and Missouri River railroad.
‡ Elevation of rails, Union Pacific railway.
§ Water surface in Kansas river.

Below the junction of the North and West Forks there are said to be flouring-mills at Crete, Wilber, and Caldwell, and there are probably available sites not yet improved. In this section the river ranges from 50 to 100 feet in width, and varies in depth from perhaps 8 inches in low water to 6 or 8 feet at a high stage. From the vicinity of Milford to Beatrice the bed is sandy and unfavorable to dams. It was stated to me that a brush dam at Crete had sunk 8 feet in the sand; and that another, at Wilber, built in horseshoe shape, had caused a very deep hole to be scoured at the center of the river below the dam, and the structure had then fallen in.

At Beatrice there is a frame dam 150 feet long and 7 feet high, resting upon a limestone bed. It was built in 1879 at a cost of $2,000. The pond sets back 2 miles up the river. The privilege furnishes a head of 7 feet, which may be increased to 9 feet. About 75 horse-power is used by a flouring-mill, with four runs of stone and a set of steel

rollers, and an elevator. Only one-half the privilege is thus employed, the remainder being unused. The mill has an abundance of water throughout the year. The river is here 100 feet wide, with banks 10 to 15 feet high. The bottom is 1 mile to 3 miles in width, and is free from swamp-land.

From Beatrice to Marysville the river bed is largely composed of magnesian limestone, with some sand-bars. Deposits of stones, such as jasper, flint, and petrified wood, are found in the bed, apparently transported from a great distance. There are large limestone quarries in the vicinity of the river, which are extensively worked. The stone is soft when quarried, but hardens on exposure. The total fall between Beatrice and Marysville is about 81 feet. I could learn of but two mills in this distance—one of two runs at Blue Springs, having a fine timber dam, and one at Oketo, with a log dam. There are said to be numerous unimproved sites, with rock bottom and available heads of 7 to 10 feet. There were mentioned in particular one 1½ miles below Beatrice; one 5 miles below Beatrice; and one 3 miles below Blue Springs.

The next power visited was that at Marysville, where there is a dam 175 feet long and 9 feet high. It was built in 1862, and consists of brush at the bottom, but above that is mostly loose rock which has been piled on. The pond sets back 3 miles in the river. A head of 9 feet is gained, and power is furnished to a fine stone flouring-mill carrying five runs, and is also transferred by cable to a grain-elevator. The race is a tunnel 250 feet long, quarried through solid rock. There is an abundance of water throughout the year, and even with the present loose dam a large amount of water runs to waste over it at all seasons.

I was informed by Mr. Milliken, county surveyor at Marysville, that from that point to the mouth of the Little Blue, the bed of the main stream consists principally of magnesian limestone. The banks are, for one-third of the way, rocky, and for two-thirds soil and clay, and average about 20 feet in height. All along this stretch there are riffles, and four or five unimproved sites can be found where there is a rock bed and an available head of 7 to 10 feet. One of these sites is about 1 mile below Marysville, and another is in section 19, township 3, range 7. It is thought that the stream might be reservoired if it were desirable. There are numerous side brooks and creeks flowing down through rocky ravines which might easily be dammed. This whole section is underlaid at slight depth by limestone of the best character for building, and the railroad from Beatrice to Marysville passes through quarries of it. Brick clay is also found in abundance. It occurs somewhat in the banks of the Blue, changing in places to a slaty rock.

Power at Blue Rapids.—The most extensively-developed power on the river is at Blue Rapids, in the southwestern part of Marshall county, Kansas. This is a beautiful town of 800 inhabitants, lying on the Central Branch of the Missouri Pacific railway, 95 miles from Atchison. It was colonized in 1869 by a society formed in Genesee county, New York. This association, known as "The Blue Rapids Town Company", purchased a large tract of land here, and set to work to develop a manufacturing town. Thirty or forty thousand dollars was at once expended in constructing a fine dam and improving the river banks. In the course of three or four years, four mills were erected and put in operation, comprising establishments for the manufacture of woolen goods, paper, flour, and plaster. During the financial depression which followed the year 1873 the woolen-mill and paper-mill were compelled to stop, and the Town Company becoming involved, its property passed into other hands. The mills were subsequently started again, and are now actively employed. The present owner of the privilege is represented in Blue Rapids by his attorney, Mr. John V. Coon.

The town takes its name from the natural rapids in the river, in which there is a fall of about 2½ feet in 150. At the head of these rapids, and some 2 miles below the mouth of the Little Blue, is the site of the dam. Directly over it is an iron road-bridge, with two spans of 118 feet each. The dam is crescent-shaped, and consists of two sections, abutting in common upon the pier at the center of the bridge. The west bank is here alluvial, while the east bank and river bed are magnesian limestone. The bed was properly leveled, and upon it was built the dam, of cut stone masonry, 8 feet wide at the base, 4 feet at the top, and 9 feet high. It is backed for 25 feet by loose stone and gravel, and at each extremity abuts upon the heavy race-way walls. In order to prevent water from working around the west end, where the bank is alluvial, a wing-wall has been carried for 50 feet beyond the abutment into the bank. This bank is also heavily rip-rapped both above and below the dam. Running from the dam down the river on each side, the whole length of the mills, there is a very solid masonry wall. The bulkhead on the east side of the river is 40 feet wide; the race has the same width, and is entered through four 8-foot arched openings in the bulkhead. The race on the west side of the river has a width of 25 feet. The present head on the wheels is 11 feet, which can be increased 2 feet by raising the dam.

The mills now in operation own rights to about 400 horse-power. It is estimated that 170 horse-power is actually used by them, (*a*) distributed as follows:

Flouring-mill, 60 horse-power (entitled to power for six runs of stone).
Woolen-mill, 40 horse-power (entitled to power for six runs of stone).
Paper-mill, 40 horse-power (entitled to 75 horse-power).
Plaster-mill, 20 horse-power.
Foundery, 10 horse-power.

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a Total rated horse-power of wheels about 317.

A wheel in the flouring-mill pumps water for the supply of the town. Besides the above mills, foundations have been laid for another, originally designed as an oil-mill.

The privilege which I have described is about a mile from the railroad, and it is probable that in time a line to follow down the course of the river will run close by it. All the work in connection with the development of the power has been done in the most substantial manner; the mills are built of stone, and it is estimated that an investment of $350,000 to $400,000 is represented at this site. No particular rates are observed in renting power; it is very much desired to attract new enterprises, and any important concern could probably obtain power free. The banks and foundations are very favorable for the location of mills, and power could be transferred to them by cables, or the races might be extended down stream. The woolen-mill is owned by the Buell Manufacturing Company, of Saint Joseph, Missouri, and is said to have met with good success. It manufactures yarns, woolen cloths, flannels, and blankets.

The river in this vicinity runs, at an ordinary low stage, 250 feet wide and 2 feet deep, with a fair current. It has risen once or twice to a height of 18 feet, but does not overflow its banks. Its low-water volume is thought to increase somewhat from year to year, by reason of the breaking up of the soil by cultivation and its consequently greater receptiveness of water. The flow from month to month is very steady. It was stated that, during the year 1880, the depth of water flowing over the Blue Rapids dam varied but three-quarters of an inch in eight months. No trouble is experienced at that point from ice. Backwater causes some hinderance during freshets, but never for a longer time than three weeks in all during the year.

I could find no record of any gauging of the river, but should estimate the power at Blue Rapids, taking the constant flow of the stream, as follows:

Estimated power at Blue Rapids.

[Drainage area 8,319 square miles.]

	Low water, ordinarily dry year.	Low water, average year.	Available 10 months in average year.
Volume, cubic feet per second	590	730	820
Theoretical horse-power:			
1 foot head	67.02	82.93	93.15
11 feet head	740.	910.	1,020.
13 feet head	870.	1,080.	1,210.

There was said to be a good unimproved site for power on the Big Blue, some 6 miles above Blue Rapids, where there is a rock bottom, and a head of 10 feet available. Another good site was mentioned as being undeveloped at Randolph, about midway between Blue Rapids and the mouth of the river, where there is also a rock bottom. There are, doubtless, numerous other available points of which I did not learn.

In its lower course the river is about 250 feet wide, and in medium low water has a depth of perhaps 4 feet, and a moderate current. It runs through bottom-land 1½ miles wide, beyond which rise bluffs 300 feet high. The banks are of loam, ranging from 10 to 30 feet in height. The bed is sandy and gravelly, with frequent limestone ledges. The last dam on the river is at Rocky Ford, 4 miles above Manhattan. It rests upon a rock foundation, and has stone abutments. It is a framed structure, 357 feet long and 10 feet high, and is reported to have cost at least $20,000. The pond sets back for 7 miles. The wheels run under a head of 10 feet, power being used by a flouring-mill with four runs of stone, and a small saw-mill. There is a large surplus of water, estimated at 10 inches in depth, running to waste over the dam at the lowest stage of the river.

The only points in the immediate vicinity of the Big Blue basin at which rainfall observations have been made for a series of years are Omaha and Fort Kearney, in Nebraska, and Manhattan, at the mouth of the river. From the records at these stations the rainfall appears to be about as follows: For the upper basin, spring, 8.5 inches; summer, 13.2; autumn, 5.8; winter, 1.6; year, 29.1; and for the basin as a whole, spring, 8.1 inches; summer, 13; autumn, 6.1; winter, 2.3; year, 29.5. In estimating the volume of this stream, in the absence of any gaugings whatever, I have divided the volume previously assumed for the Kansas river mainly among its three largest tributaries, the Republican, Smoky Hill, and Blue. I have given to the latter stream a considerably higher and less variable rate than to either of the former, in accordance with its character as having a steady and well-sustained flow. This character is probably due to its being well supplied by springs, to the greater cultivation of the soil in the Big Blue basin than in western Kansas and Nebraska, and to the fact that, to a large extent, it flows directly upon the rocky strata, which shed water into it, while the Republican and Smoky Hill are underlaid to a greater or less depth by sand and other surface deposits, which must permit a great deal of water to percolate through them and be lost to the streams.

Estimated volume and horse-power, Big Blue river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Crete	2,711	150	170	220	250	250	280
Beatrice	3,841	240	270	330	370	370	420
Above Little Blue	4,858	320	360	420	480	470	530
Below Little Blue	8,319	590	670	730	830	820	930
Randolph	9,372	660	750	800	910	910	1,030
Mouth of river	9,574	670	760	820	930	930	1,060

TRIBUTARIES OF THE BIG BLUE.—Ascending from the mouth, Fancy creek is the first side stream of any consequence. It enters the main river from the west at Randolph, and is used for power by one small flouring-mill.

The next tributary is the Black Vermilion, which joins the Big Blue from the east about 10 miles southeast of Blue Rapids. It drains an area of 533 square miles, lying mainly in Marshall county. At Frankfort it has a mill of two or three runs. The bed is to a considerable extent rocky, but the stream gets very low in a dry season, and is not of importance for power.

The Little Blue river.—This is the next and most important tributary of the Big Blue. It heads in Kearney and Adams counties, in southern Nebraska, pursues a southeasterly course into Kansas, and joins the Big Blue 2 miles above Blue Rapids. It is 158 miles long by general course, with a drainage area of somewhat uniform width, comprising 3,461 square miles. The headwaters of this stream are within a few miles of the Platte river, and the underground drainage which both it and the Big Blue receive from the Platte has already been discussed in connection with the latter river. For a distance of 40 or 50 miles its course is closely followed by the Saint Joseph and Western division of the Union Pacific railway.

The country drained by the Little Blue is open and rolling. Corn, wheat, and other grains are the chief productions, but toward the headwaters the rainfall is rather scant and unreliable, and failures of crops are not uncommon. The main stream is fringed with cottonwood and box-elder, but there is more timber on the little side streams, consisting of oak, walnut, and ash. There was formerly much more timber in this section than now, but it has largely been cut away, both upon this river and the Big Blue. Building-stone is found at Hanover, Hollenberg, and in Thayer county, but not above. The river bed is sand and gravel, underlaid by a very hard clay which is almost stone. I was informed by Mr. W. W. Watson, (*a*) civil engineer, of Fairbury, that in excavating in the river bed for pier foundations he had found a thin shale, and under this 3 feet of quicksand, underlaid in turn by the hard clay above mentioned. The banks are usually of loam, and 6 to 8 feet high; sometimes, where the stream cuts into the bluff, red sandstone crops out.

The river is bordered by bottom-land averaging a mile or more in width. Beyond this rise, on either side, low bluffs, 50 or 60 feet high. The stream has a swift current and a quite steady flow from month to month. It rises and falls rapidly, however, after heavy rains, and occasionally overflows its banks; it did so in the fall of 1869, and again in 1874. Summer high water commonly sets in about June 1, and a high stage lasts for a week. For that length of time the mills are troubled by backwater. Ice causes no difficulty. Mr. Watson does not consider storage reservoirs very practicable along this stream, even if they were needed. He says there are neither favorable ravines on the small streams nor natural ponds.

Slope of the Little Blue river (approximate).

Locality.	Elevation above sea.	Fall. between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Hastings (4 miles from river) †	1,886	562	81	6.9
Fairbury ‡	1,324			
Mouth of river §	1,107	217	47	4.6

* Map measurement.
† Elevation of rails, Burlington and Missouri River railroad.
‡ Elevation as given by Professor Aughey.
§ Elevation estimated.

a I am indebted to Mr. Watson for most of my information concerning this river.

Only a small proportion of the fall of this river is in use, and it was stated that a good available power could be found once in 3 miles, on the average, where 10 feet head might be secured. As nearly as I could ascertain, the locations of the mills on the river were as follows, beginning at the head: Adams county, one mill; Clay county, one mill of two or three runs; Nuckolls county, two mills of two or three runs each; Hebron, one mill of four runs; 5 miles above Meridian, one mill of two or three runs; Meridian, one mill of three runs; Fairbury, one mill of four runs; Steele City, one mill of three runs; Hanover, one mill of four runs; 3 miles above Waterville, one mill of four runs; and at Waterville, one mill of four runs. These are all flouring-mills. The dams are said to range in length from 100 to 200 feet, in height from 7 to 10 feet, and in cost from $1,000 to $3,000. I was told that they were originally of brush in most cases, but are being gradually replaced by crib-work structures, the latter being more permanent and requiring fewer repairs. Brush dams sink in the sandy bed, and settle even on a hard foundation; they also decay quite rapidly, and need repairing every year.

At Fairbury the Little Blue is, at mean low water, about 80 to 100 feet wide, and 2 feet deep; at mean high water it has nearly the same width, but is probably 10 feet deep. The dam at this point was in the first place brush, but a new dam, of crib-work filled with stone, was built in 1877 below the old one, and the intervening space filled with stone. It cost about $3,500, is 150 feet long, 7 feet high, and has stone abutments. The pond extends 1½ miles up the river. The wheels run under a head of 7 feet, and are located in a wheel-pit at one end of the dam. The power is taken from a 61-inch Leffel wheel, and transferred by a ⅝-inch wire cable 730 feet to the mill. The plan is very satisfactory in its working. The wheels are rated at 55 horse-power, and there is a large surplus of water at the lowest stage.

Toward the mouth of the river the bed is generally gravel. As a rule the banks are bluffy on one side, and low upon the other; the low bank is about 8 feet high and is sandy. The stream overflows its banks every few years in this section, and then runs 300 feet or more in width. The extreme freshet rise is 14 feet. The last power on the river is at Waterville, a few miles above the mouth, and is occupied by a four-run flouring-mill, with wheels of 90 horse-power. The dam was built in 1873, and cost $11,000. It is 170 feet long, 15½ feet high above foundation, is of stone laid in cement, and measures 9 feet in width at the base and 6 feet at the top. It rests upon a rock bed, has masonry abutments, and is without any apron. The pond sets back 3 miles. The fall is 6½ feet. There is, of course, an abundance of water at all stages.

Of the tributaries of the Little Blue, the Big Sandy and Rosewater are small and unimportant, but are used by one or two little flouring-mills. Since 1871 the Big Sandy has increased 1½ to 2 miles in the length of running water at a low stage.

The mean rainfall on the drainage basin of the Little Blue is, approximately, in spring, 8 inches; summer, 11; autumn, 5; winter, 1½ to 2; year, 25½ to 26. Further on will be found an estimate of volume and horse-power at different points.

Other tributaries of the Big Blue.—Between Beatrice and Crete the Big Blue receives Turkey creek on the west side. It has a drainage area of 686 square miles, lying in Saline and Fillmore counties, and is used for power by several small flouring- and grist-mills.

The West Fork of the Big Blue is formed in turn by Beaver creek and the South Branch, which have their sources respectively in Hamilton and Adams counties, Nebraska, whence they run easterly. The West Fork unites with the North Fork a few miles above Crete to form the main Blue. It has a length of about 90 miles by general course from the head of the South Branch, and drains 1,357 square miles. Power is used by a considerable number of flouring-mills, of which I learned the locations of six to be as follows, in order from the mouth: West Mills, Beaver Crossing, Blue Valley, Fillmore, point 2 miles west of Fillmore, and Farmer's Valley. These mills were all said to have two runs of stone each, except that at Beaver Crossing, which has three runs. This stream is reported to be about 50 feet wide, and to have rather low banks, so that there is danger of flooding in high water.

The North Fork of the Big Blue rises in Hamilton county, within a few miles of the Platte. It runs easterly and then southerly, finally uniting with the West Fork. Its length by general course is about 80 miles, and its drainage area 1,326 square miles, or nearly the same as that of the West Fork. The surface of the country is similar to what has been so frequently described for neighboring streams. Brick-clay is found above Seward, but no timber or stone of consequence. The highest mill on the stream is a small one of two runs at Ulysses. There are doubtless available sites for power to be found above Seward, but the volume of the stream is said to be small at a low stage, and it is difficult to find firm foundations for dams. In the vicinity of Seward the North Fork is 50 to 75 feet wide at a mean stage. The bed is of mud, underlaid by clay; the banks are of loam, and 15 to 25 feet in height.

The next power used below Ulysses is at Seward. The dam is of brush, 75 feet long, and 8 feet high. It was built in 1868, and is stated to have cost $1,100. The pond sets back 3 miles. The wheel is of 35 horse-power, and runs under a head of 8 feet. The mill carries two runs of stone, and obtains sufficient water for running at full capacity nine to ten months in the year, and half capacity the remainder of the time. During the summer rise considerable trouble is experienced for two or three weeks from backwater. There is said to be a mill of three runs 1½ miles below Seward. The only other mill on the North Fork is at Milford, some 7 miles above the junction with the West Fork. The power is owned by Mr. J. H. Culver, who has in operation a flouring-mill with four runs of stone, and four rollers for the Washburn process, each set of rollers requiring about the same power as one run of

stones. About 150 horse-power of wheels are in use, and there is abundance of water for running at full capacity throughout the year. The dam is of brush, stone, and gravel, and was built in 1866 at a cost of $3,000. It is 178 feet long, 10 feet high, and gives a head of 10 feet on the wheels. The foundation is magnesian limestone. The pond is estimated to set back 7 miles, measured along the river's course, and to average 125 feet in width and 8 feet in depth. Mr. Culver states that, at Milford and below, the Blue is crossed by a magnificent belt of magnesian limestone, 5 miles in width, and that in this belt there are four good unimproved sites for power, at which heads of 9 feet can be secured. One of these was to be used, in the spring of 1881, for the manufacture of straw paper. Below the stone belt, to Beatrice, the river bed is said to be sandy, and less favorable for water-power sites. At Milford the North Blue has an average width of about 100 feet, running perhaps 8 inches deep at low water, and 6 to 8 feet at mean high water.

Lincoln creek joins the North Fork at Seward from the west. It is 64 miles long by general course, and is used for power by 1 or 2 small mills. The width near the mouth is about 50 feet, and the drainage area 447 square miles.

Tributaries of the Big Blue river.—Estimated volume and horse-power.

Stream.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Black Vermilion	533	30	34	40	45	50	57
Little Blue:							
At Ox Bow	954	60	68	90	102	100	114
Below Big Sandy	2,097	140	159	190	216	210	239
At Hanover	3,186	210	239	280	318	320	364
At mouth	3,461	220	250	310	352	350	398
Big Sandy creek *	565	30	34	50	57	60	68
Turkey creek	686	40	45	60	68	70	80
West Fork Blue	1,357	70	80	110	125	120	136
North Fork:							
Below Lincoln creek	1,090	60	68	90	102	100	114
Above West Fork	1,326	70	80	110	125	120	136
Lincoln creek	447	20	23	35	40	40	45

* Usually dry, except in high water, above a distance of 15 miles from the mouth.

THE REPUBLICAN RIVER.

Formed by a number of small forks which head in eastern and northeastern Colorado, the Republican enters Nebraska and flows more than half way across the southern part of that state, the main stream being nowhere more than 20 miles above the Kansas boundary. It finally enters the latter state, and, taking a southeasterly course, unites with the Smoky Hill to make up the Kansas river. Measured from the sources of the Arickaree and South Forks it has a length, by general course, of about 430 miles. The water-shed lines cannot be traced with accuracy upon any maps now in use, but probably include a drainage area of about 24,600 square miles. The country embraced is not essentially different in outward appearance from that drained by the Blues. As a whole, however, it is less fertile, and has not, perhaps, so much timber; in fact, the upper basin of the Republican has so small and uncertain a rainfall, and so light a soil, that it has little value for agriculture. In that section there are scarcely any settlements, but after the river has passed well to the eastward, in Nebraska, there are frequent small towns along its course, with a few hundred inhabitants each, and in Kansas it enters a comparatively well settled region. The larger towns on its course are Junction City, population, 2,700; Clay Center, 1,800; Clyde, 900; and Concordia, 1,900. The Burlington and Missouri River Railroad Company have been constructing a line to Denver, following up the Republican valley from Red Cloud, and early in 1881 it was in operation to Indianola, in Red Willow county.

The bed of the Republican river is at almost all points sand, and is to a great extent shifting quicksand of the most unstable character. In some localities it is underlaid at a moderate depth by limestone rock, and this even forms the immediate bed at a few places; but usually the bed is as above described, and evidently very unfavorable to the security of dams. The river is wide and rather shallow, with a rapid descent. It is subject to sudden rise and fall, and occasionally overflows in its lower course. It carries considerable drift, and is sometimes gorged by ice. Its upper waters extend to the basins of the Arkansas and Platte, and from the latter stream it is thought to receive underground drainage, just as do the Blues farther east. The sandy bed of the Republican is supposed to be continuous with a stratum of sand underlying the whole region and constituting the plane of drainage. Whenever wells are sunk to this plane water is reached. Under the bluffs it is, of course, deep below the surface, in proportion to their height, and I was told that south of the Platte, on the divide between that river and the Republican, a well was bored 230 feet before reaching this water-bearing stratum.

The principal rise in this river occurs early in June, from which time high water continues till about the 1st of August. During this period heavy and protracted storms occur, and the stream rises rapidly, to fall away in a day or two. After August 1 it sinks away quickly and reaches a low-water stage, which remains substantially the same till the next June rise.

Slope of the Republican river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Head of Rock creek†	4,050			
		450	60	7.50
Western line of Nebraska†	3,600			
		840	78	10.77
Culbertson†	2,760			
		160	29	5.52
Indianola†	2,600			
		350	32	10.94
Arapahoe†	2,250			
		100	36	2.78
Orleans†	2,150			
		766	148	5.18
Concordia‡	1,384			
		97	19	
Clyde§	1,287			
		68	38	3.23
Clay Centre‡	1,219			
		61	13	
Gatesville§	1,158			
		88	30	2.93
Mouth of river (water surface)	1,070			

* Map measurement.
† Elevation given by Professor Aughey in *Physical Geography of Nebraska.*
‡ Elevation by Union Pacific railway levels (rails).
§ Elevation by Union Pacific railway levels (water surface).

NOTE.—There are such changes in the slope, according to the above table, that I can hardly believe all the figures reliable; still they will give some idea of the descent in different portions of the river.

Professor Aughey thus writes, in the *Physical Geography of Nebraska*, concerning one of the streams which go to make up the main Republican, and which he evidently regards as the principal source:

The Republican river rises in the Colorado plains, near range 49, west of the sixth principal meridian. Here, anciently, there was a lake, whose basin was about 4 miles across. The outlet, or river, draining it, however, long since cut down the narrow rim and drained the lake. Its head here in the old lake is 4,050 feet above the sea. A few small springs now rise below the site of this old lake, and produce a tiny streamlet, a foot across. Other streams, about or nearly as large, soon join it, but at the state line I could still, when there in the spring of 1877, jump across it. Along this part of its course there are a few beautiful little lakelets, into which and from which it flows. Here the water is cool and clear as crystal. When it receives the water of the Arickaree, about 7 miles east of the state line, it assumes its characteristic character.

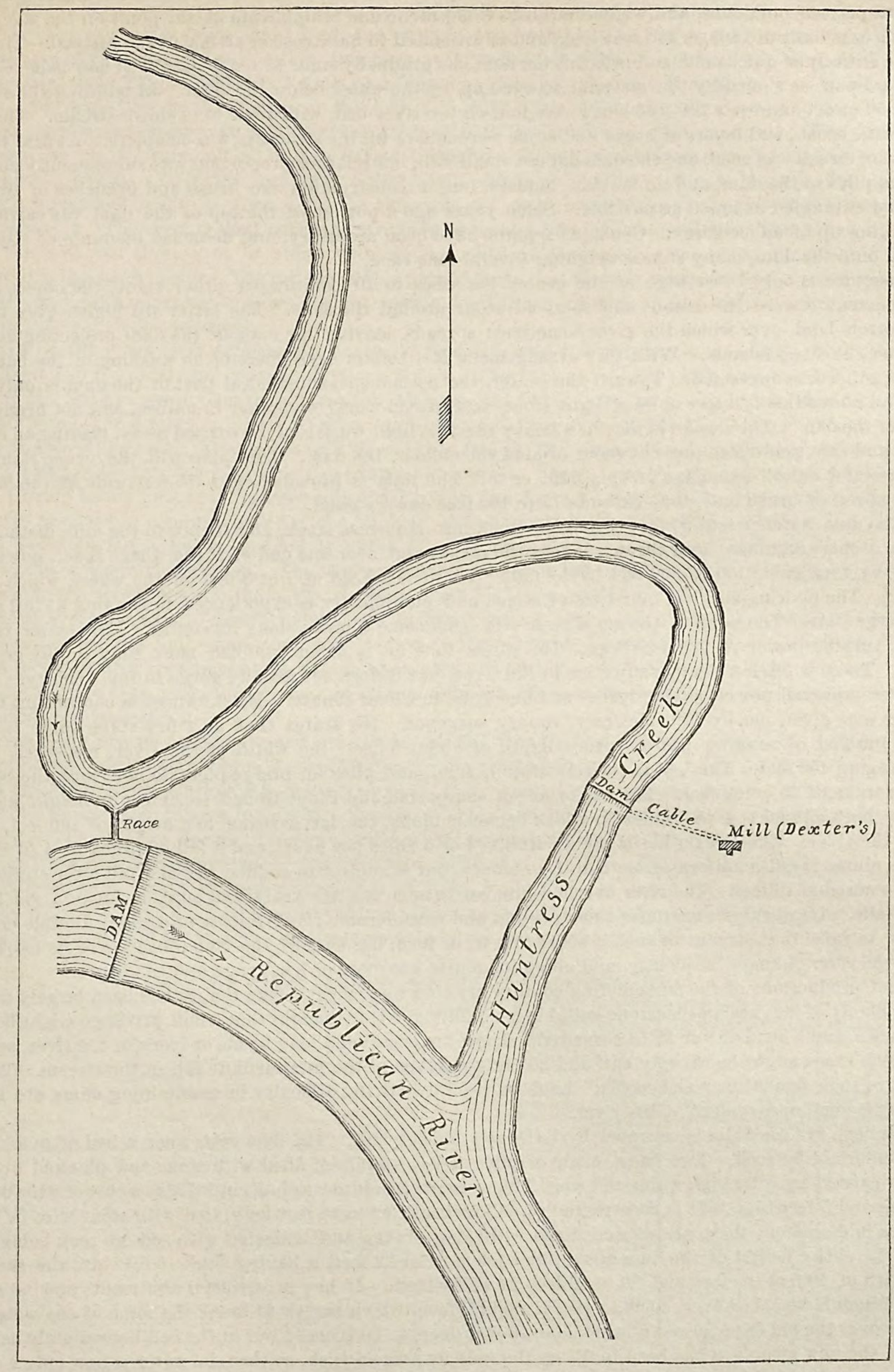
It now becomes shallow and sandy, and in places rapid. Its principal tributary in this portion of the state (Nebraska) is the Republican Fork, and comes from the southwest. Its junction with the Republican is in range 38 west. Frenchman's Fork (*a*) is an important tributary that rises in Colorado, and, flowing southeast, joins the Republican at Culbertson. After this the most important tributary from the southwest is the Beaver. Red Willow and Medicine creeks, from the northwest, are also important tributaries. An immense number of small creeks flow every few miles into the Republican, especially from the north. This river, unlike the Platte, increases regularly in breadth and volume all the way from its source to its exit from the state in Nuckolls county. It is forded in many places, and the only danger is from quicksands.

Toward its mouth the Republican is fringed with a moderate amount of timber, and runs with very winding course through a valley one-half to three-quarters of a mile wide. The banks are 5 to 10 feet high. The bed is sandy, and numerous bars and islands are to be seen. The first point at which power is used, in ascending the stream, is Clay Center, in Clay county, 30 miles or so by general course from the mouth. The river is here said to be 500 feet wide in high water, and 4 to 10 feet deep; while in a low stage the width scarcely includes 100 feet of running water. The current is very swift, and the flow reasonably steady from month to month. The bed is, to a considerable extent, quicksand. Mr. McLaughlin, deputy county surveyor, said that piles had been driven 14 feet into the sand, in founding bridge-piers, without reaching any solid foundation. The bed shows numerous sand-bars, and is very changeable. The banks are of loam, and usually about 10 feet high, but in places where the river cuts into the bluffs reach a height of 60 feet on one side, but are low on the opposite side.

The river has overflowed its banks in this locality twice during fifteen years, running at such times half a mile to a mile wide. The bottom-land is 1½ to 2 miles wide between the bluffs, which are quite low. A fair amount of timber is found in this section, principally ash, hickory, oak, cottonwood, elm, and white oak. Corn and wheat are the staple products, the bottom-land being best suited to the former. There is an abundance of blue and magnesian limestone, and sandstone both red and gray. The river is used only to a small extent for water-power, mainly from a lack of capital and the difficulty of maintaining dams.

In view of the latter fact it is interesting to note the experience of Mr. Dexter, proprietor of the privilege at Clay Center. He at first received great discouragement from the settlers there, and was assured that a structure

a Whiteman's Fork on the maps.



WATER PRIVILEGE AT CLAY CENTER.

could not be built which would withstand the river. He persevered, however, and succeeded in building a dam in which he has perfect confidence, and which he thinks it is practicable to duplicate at any point on the river.

The dam was built in 1865, is 450 feet long, and is estimated to have cost in all $30,000 to $40,000. The bed at this point is entirely of quicksand, and into this the dam has gradually sunk 15 to 30 feet; it is now believed to rest firmly on hard-pan, as shown by the material scoured up by the water below the dam. In building the structure large trees, 50 or 60, and even 100 feet long, were laid on the river bed, with their buts down stream. The spaces were filled with brush, and layers of brush and stone were added till the structure was complete. At first too small a proportion of brush was used, and the dam did not stand well, but a larger proportion was subsequently employed. There are no piles in the dam, and no vertical binders, but in construction the brush and branches of trees were entwined and entangled as much as possible. Some years ago a portion of the top of the dam was carried away on the breaking up of an ice-gorge. Constant repairs have been necessary, and immense amounts of stone have been hauled onto the dam, many stones weighing several tons each.

The structure is only 7 feet high at the center, but rises to 10 feet toward either shore, the object being to throw the current toward the center, and so avoid scour around the ends. The latter are higher even than the adjacent bottom-land, over which the river sometimes spreads, leaving the ends of the dam projecting above the water surface, like two islands. With this arrangement Mr. Dexter says there is no washing of the banks, and they are not otherwise protected. Toward the center, the permanent, substantial part of the dam is only 5 to 5½ feet high, and above this is 2 feet or so of light stone- and gravel-work, temporary in nature, and not firmly united to the rest of the dam. The design is that in a heavy rise this light work shall be carried away, making an enlarged water-way, and also tending to prevent scour around the ends of the dam. This plan will, the owner thinks, save the structure, and entail a damage of only $100 or so. The dam is probably 60 to 75 feet wide at the base, and below it an apron of brush and stone extends 75 to 100 feet down stream.

From the dam water passes 90 feet through a canal into Huntress creek, and thence to the mill, distant half a mile. Here a short dam has been thrown across the creek, and near one end of it the wheel is set, power being transferred by wire cable 150 or 200 feet to the mill. There is a head of 7 or 8 feet on the wheel, which is of 65 horse-power. The flouring-mill has four runs of stone, and no difficulty is experienced in running at full capacity throughout the year. The pond in the main river sets back some 4 miles along its course. Mr. Dexter is willing to rent the surplus power at his privilege. He states that he is never troubled more than a day or two by backwater. There is often a heavy run of ice in the river, but it does not usually gorge in this vicinity.

The next improved power on the river is at Concordia, in Cloud county. My information concerning this part of the river was given me by Mr. McCrary, county surveyor. He states that in a low stage there is a width of perhaps 160 feet of running water, with a depth of about 3 feet, the width of the river, measured between banks, averaging 450 feet. The bed is entirely of quicksand, and piles for bridge-piers do not reach the bottom of it, even at depths of 15 or 20 feet. The banks are of sandy soil, and range from 3 to 20 feet in height above low water. The bottom-land is 4 to 5 miles in width between bluffs, the latter rising to a height of 100 feet, more or less, above the river. The stream has a rapid current (4 or 5 miles per hour), and a fall of probably 4 to 5 feet per mile. The volume is quite uniform, from month to month, but is subject to sudden rise and fall after storms. The extreme rise noted is 16 feet. The river overflows its banks once in a few years, and spreads out to a width of half a mile or a mile. Local rains sometimes cause a rapid and considerable rise. Such a rain, along Buffalo creek, has been known to raise that stream to such a point that it, in turn, has carried the Republican over its banks. The channel of the river changes frequently, and along its course are more or less snags and sand-bars.

The chief productions of the surrounding country are corn and wheat. The timber has been largely cut away, but there is plenty of magnesian limestone suitable for building. It is thought that a mill privilege might be formed every few miles, and a head of 8 or 10 feet secured. There are occasional long bends or loops in the river, across the necks of which races might be cheaply cut, and advantage taken of the intermediate fall in the stream. There are said to be two such bends near Concordia. Lack of capital and the difficulty in maintaining dams are given as the reasons for non-improvement of the river.

The privilege at Concordia is occupied by LaDoue's flouring-mill. The dam rests upon a bed of quicksand 20 feet deep, underlaid by rock. Two dams, made of piles and sheet-piling, filled with stone and planked over, were successively carried away by high water and ice. The present structure was built in 1873, at a cost of $10,000, and is 420 feet long and 5 feet high. It is constructed of willow brush 12 to 18 feet long, tied with stout wire in bunches 6 or 8 inches in diameter; these are pinned down with long stakes and ballasted with sod, no rock being used in the dam. The entire height of the dam above the base is 21 or 22 feet, it having sunk 16 feet into the sandy bed. It has a width of 40 feet on top, and 50 to 60 feet at the bottom. It has no artificial abutments and no separate apron; the brush is laid, however, so as to give a sloping face, which serves to break the force of the water. The fall of water over the old dam caused a large hole, 16 feet deep, to be scoured out in the bed immediately below, but the effect of the new structure has been to fill up the hole by a back-wash, so that the water is now only 2 or 3 feet deep. There is a head of 5 feet on the wheel. The mill carries three runs of stone, utilizing 40 horse-power, for which there is an abundance of water at all times, with no trouble from backwater. The water-wheel is located at one end of the dam, and power transferred to the mill by a shaft 100 feet or more in length.

The only mill above Concordia, in Kansas, is at Scandia, in Republic county. Entering Nebraska we find mills at the following points, in order: Superior, one mill of three or four runs; Guide Rock, one mill of two runs, not in operation; 1½ miles west of Red Cloud, one mill of three runs; one mill of three runs in Franklin county; one of two runs at Orleans, and one mill of four runs at Arapahoe, in Furnas county. The dams at these places are said to range from 250 to 400 feet in length, and from 8 to 15 feet in height. They are said to be mostly framed structures, and, according to the nature of the bed, are built either of bents bolted down to rock, or of piles surmounted by capping-pieces and planking, the whole backed by brush and other material. The power at Red Cloud is used by the flouring-mill of Messrs. Potter & Frisby. They have a timber dam, which was built in 1875 and cost about $4,000. It is 350 feet long, 5 feet high, and is in the form of a half-circle, having its crest immediately supported by 9-inch piles, driven at intervals of 7 feet through the sandy bed to the limestone rock which underlies it. The crest is shod with iron straps to prevent injury by ice and drift. The fall at the dam is 5 feet, and the mill has three runs of stone, with water-wheels of 50 horse-power. A small saw-mill is run in connection with the same power. The owners of this privilege say that there is an abundance of water at all seasons for their use, and a considerable surplus. Slight trouble is experienced with anchor ice in the fall, and for about one week in the year with backwater.

The river in this vicinity is, at mean low water, 80 feet wide and 2 feet deep; at mean high water the average width is about 420 feet, and the depth is perhaps 4 feet. The current is very swift, and the fall rapid. I was informed by Mr. Strohm, county surveyor, that the fall near Red Cloud is 14 feet per mile, and that 28 miles to the west he had found it 15.6 feet per mile. Another gentleman gave the average fall of the river through the county as 7 feet 8 inches to the mile. The flow is said to be quite steady, the river seldom overflowing its banks and not being much affected by any but very heavy or protracted storms. Heavy masses of flood-wood float down stream at times. During heavy runs of ice, gorges occasionally form and cause a set-back in the river, and in one instance, at least, have resulted in a submergence of the banks. The channel shifts frequently. The bed is occasionally a magnesian limestone ledge, but in general is a kind of quicksand, about 10 feet deep, extending out in a uniform plane under the surrounding country. The banks are usually of loam, and are 5 to 6 feet in height; in some places, however, where the river cuts into the bluffs, they are much higher on one side.

The bluffs average about 75 feet in height, and inclose between them about 3 miles in width of bottom-land, of which 1½ miles belongs to the lower or "first" bottom. The surrounding country is open and rolling. The main stream and its tributaries are fringed with a moderate amount of timber, comprising cottonwood, elm, ash, box-elder, and walnut. Corn, wheat, and other grains are raised. The soil is good, but the climate is rather dry, and in some years the crops are very small.

I believe there are no long-continued records of rainfall for points within the Republican basin. Judging, however, from the Smithsonian tables, I should estimate the precipitation to be about as follows:

1. For the lower river: Spring, 6.5 inches; summer, 10.5; autumn, 5.5; winter, 2; year, 24.5.
2. For the upper basin (above Indianola): Spring, 4 inches; summer, 5; autumn, 3; winter, 1; year, 13.
3. For the entire basin: Spring, 6 inches; summer, 8; autumn, 4; winter, 1.3; year, 19.3.

I cannot learn that any measurement has ever been made of the volume of the river, except one by Professor Aughey, in July, 1876, which showed a discharge of 1,638 cubic feet per second (*a*) at the boundary between Nebraska and Kansas; but the river was probably much above its low-water stage at that time. I estimate roughly the volume and theoretical horse-power of the stream as in the accompanying table:

Estimated volume and horse-power of the Republican river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Indianola	12,884	200	230	350	400	430	490
Below Beaver creek	19,263	400	450	650	740	800	910
Bloomington	20,973	430	490	710	810	870	990
Red Cloud	21,593	450	510	730	830	890	1,010
Kansas boundary	22,085	530	600	800	910	970	1,100
Concordia	23,253	590	670	890	1,010	1,080	1,230
Clay Center	24,227	700	800	980	1,110	1,190	1,350
Mouth of river	24,587	725	825	1,000	1,140	1,230	1,400

TRIBUTARIES OF THE REPUBLICAN RIVER.—Regarding the tributaries of the Republican, I have but little information. Buffalo creek enters the main stream from the west, a short distance above Concordia, and is reported

a 0.074 cubic foot per second per square mile of drainage area.

to have one mill at Jamestown, with a stone dam 16 feet high. The other little streams in that section would carry small powers for part of the year. White Rock creek, which joins the Republican from the west not long after it enters Kansas, drains 387 square miles. It has high banks, rock ledges in its bed, and a well-sustained volume, but is subject to heavy rise and overflow. It is used for power by two small mills.

Of the tributaries received in Nebraska, Turkey creek has one mill in Franklin county. Prairie Dog creek comes from the southwest, and lies mainly in Kansas. It drains 1,021 square miles, and is used for power by half a dozen flouring-mills. Beaver and Sappa creeks drain long, narrow strips in northwestern Kansas, and unite shortly before they reach the Republican in Nebraska. They are improved by one or two small mills, and are said to be very good streams for power, especially Beaver creek. They have a combined drainage area, at the junction with the Republican, of 4,050 square miles, while Sappa creek alone drains 1,740 square miles. Frenchman's Fork has an 18-foot fall over rock, and Red Willow, Indian, Elm, and Farmer creeks are all reported to be suited to small powers.

I secured no information about the other tributaries of the Republican, but all those which I have mentioned could probably be relied upon throughout the year for powers of moderate size. It is said that none of them ever run dry; on the other hand, they are well sustained in flow, have a good fall, and favorable beds. They rise and fall rapidly during summer rains, and in some cases overflow the bottom-lands widely.

THE SMOKY HILL RIVER.

This stream, the last tributary of the Kansas river to be described, rises near the boundary between Kansas and Colorado, whence it pursues a winding, but on the whole easterly, course through Kansas, till in Davis county it unites with the Republican. It has a length by general course of 310 miles, and a total drainage area of about 20,000 square miles. East of Salina the river is a constant succession of bends, and in Dickinson county its actual length is at least twice as great as the distance by general course. The only important tributaries are the Saline and the Solomon, which enter the lower river from the north, their courses, however, being in the main parallel to the Smoky Hill.

The Kansas Pacific railway follows the latter river from its mouth to Salina, strikes it next at Fort Harker, and finally at Wallace, near the headwaters. Along the line of this road, where it borders the river, are a number of enterprising towns, of which the most important are Junction City, at the mouth of the river, population, 2,700; Abilene, 2,400; Solomon City, 600; Salina, 3,100; and Ellsworth, 900.

Slope of the Smoky Hill river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Wallace †	3,345			
		1,815	211	8.60
Ellsworth ‡	1,530			
		210	56	3.75
Lindsborg ‡	1,320			
		130	38	3.42
Mouth of Saline ‡	1,190			
		24	13	1.85
Mouth of Solomon ‡	1,166			
		96	77	1.25
Mouth of Smoky Hill §	1,070			

* Map measurement.
† Rails, Kansas Pacific railway.
‡ Kansas Pacific railway levels, water surface.
§ Water surface.

The Smoky Hill river is distinguished by a sandy bed, rapid fall, and variable flow. Its volume is at certain seasons very small, and in the upper course it is for much of the time entirely dry.

The first power met in ascending the river is at Junction City, and but a short distance above the mouth. At the site of the dam the river bed contains a rock ledge, dipping from the surface on one side to a depth of 15 feet beneath the surface on the other. Overlying this rock is sand, and upon this the dam rests most of the way. It is a framed structure, abutting against the mill foundations at one end and against a crib filled with stone at the other. It is 160 to 175 feet long, 9 feet high, and was built in 1864. Above the dam the river bed is covered with stone, and below it an apron is formed by timber and stone crib-work. The pond sets back 6 or 7 miles. A wheel of about 60 horse-power runs under a head of 9 feet, and supplies the mill with power for four runs of stone. There is always a large surplus of water, and the owner even estimates his privilege to be good for 500 horse-power throughout the year. He claims to have no trouble from ice or backwater.

In this portion of its course the Smoky Hill has a size, at mean low water, of 130 to 160 feet by 3 feet; in mean high water it is 175 feet wide and 15 to 18 feet deep. The current is strong at all times, and during high water is very swift. The bed is of ordinary sand or quicksand, and shows rock ledges in the shoals. The banks are sandy, and

10 to 12 feet in height. Black walnut, hackberry, oak, and other varieties of timber fringe the side streams, about 5 per cent. of the surface of Davis county being wooded. The bottom-land is 1 mile to 2½ miles in width, and bordered by low bluffs. The bottoms yield large crops of corn, but on the uplands wheat is more generally raised. Magnesian limestone is found in abundance. It was stated to me that there are fine sites on this part of the river, unimproved for lack of capital, and that custom mills are very much needed. The present mills do a large business, and find so ready a sale for their flour in Colorado and Texas that they do not undertake much custom business.

At Enterprise there is a fine flouring-mill with four runs of stone, followed by mills at Abilene and Salina. The dam at the latter point rests upon a quicksand bed, and consists of a mass of loose rock, packed as closely as possible and surmounted by a low framed structure. It is obtuse-angled in plan, the vertex being up stream, of course, and abuts at each end upon timber cribs, one filled with stone and the other with clay. The river banks are protected by rip-rap below the dam. The mill uses a head of 8 feet, and has five runs of stone. There is trouble here for about two weeks in the year from backwater.

At Salina the Smoky Hill is, in mean low water, about 40 feet wide and 2 feet deep; in high water it is 150 feet wide and perhaps 25 feet deep. The bed is composed, at various points, of firm sand, quicksand, gravel, and occasionally sandstone or limestone ledges. The banks are of loam, 25 feet high, and are seldom overflowed to much extent. High water occurs in June, but may come at any other time, as it results from rains, and not from the melting of snow, the amount of which is small in the Smoky Hill basin. There is a fair amount of timber bordering this part of the stream, mostly cottonwood, with some hackberry, box-elder, and elm. Plenty of fine building-stone is found, comprising blue limestone, gypsum, and red and gray sandstones.

There is reported to be a good unimproved site for power 2 or 3 miles below Salina, where a head of 7 feet could be secured. There are two or three mills on the Smoky Hill above Salina, but I am unable to give their location.

Above Ellsworth, distant from the river's mouth about 100 miles by general course, this stream has little or no value for power on account of its sandy bed and small volume, which sometimes entirely disappears during the warm season. At Ellsworth the Smoky Hill is, at a mean low stage, 50 to 75 feet wide and 1 foot deep; at mean high water it is about twice as wide, and in the highest known rise has attained a depth of 20 to 23 feet. It occasionally overflows in places, and because of its exposure to such accidents the village of Ellsworth was removed to its present position from a point 1 mile farther down stream. The river bed is in this locality mostly a firm sand, and the banks are of clay and sandy loam, 10 to 15 feet in height. The valley is three-quarters of a mile to a mile and a half in width, and exhibits a gradual rise on the north side, without bluffs. At Wilson, 10 miles above Ellsworth, there are bluffs 125 feet high on the south side of the valley.

Opposite Russell, 35 miles westerly from Ellsworth, the river is at mean low water about 60 feet wide and 6 inches deep; and at mean high water about 160 feet wide, with a depth of 7 feet. The valley is 1½ to 2½ miles in width, and is bordered by bluffs 180 to 200 feet high. The river bed is of quicksand. For 3 feet in depth it has a light color, but lower down is a very sharp, black sand. A great deal of magnesian limestone is found in this region, and in Russell I saw buildings constructed of bricks of that material. The bricks were of the ordinary size, sawed out of the limestone, and said to be furnished at $7 per thousand.

The last point visited was Hays City, which is about 12 miles north of the main river. In this locality, not more than midway between the mouth of the river and its extreme source (*a*) on the Colorado line, and with a drainage area above of 6,000 square miles, the Smoky Hill has a size in mean low water of about 10 feet by 4 inches; and this size is seldom much exceeded, except temporarily after a heavy storm. It frequently disappears entirely in its bed of quicksand during summer, especially if there has been but little snow during the preceding winter. There is usually a moderate current of about 3 miles an hour. The stream is clear, and is subject to rapid oscillations after storms, never rising, however, more than 5 or 6 feet. The banks are sandy and low, and in some places the river submerges the first bottom, but this is very narrow. Above Hays no timber whatever is found on the Smoky Hill, and none worth mentioning on any of its tributaries.

The river valley is in this vicinity about 3 miles wide between the bluffs, but of this distance not more than half a mile is level ground, the remainder being a gradual or broken rise. The country drained has a good soil, but insufficient rain. Considerable wheat and corn is raised, and the crops are generally good, but yet failures are not uncommon. The wheat crop was a failure in both 1879 and 1880. A gentleman who has lived at Hays ten or fifteen years says there has been no observed increase in the annual rainfall in that section, in the size of small streams, or in the number of springs; but still he thinks the rains are somewhat less violent and are better distributed than formerly, and that the average humidity of the atmosphere is greater. As an evidence of the natural fertility of the soil, he states that when there is abundant rain vegetation grows with great luxuriance. As we advance westward the soil grows lighter, and near the Colorado line probably is of little value.

The surrounding country contains plenty of ordinary and magnesian limestones, and bituminous coal of an inferior quality is found in Russell county. In Ellis and Trego counties there are immense deposits of pure white chalk in the bluffs along the Smoky Hill. In Trego county there are also beds of a very fine sand, said to be valuable for polishing machinery.

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a Probably for flood drainage only.

From the Smithsonian tables I estimate the average rainfall on the Smoky Hill basin as follows: Above Hays, spring, 5.7 inches; summer, 5.6; autumn, 4.9; winter, 2.6; year, 18.8; for the entire basin, spring, 5.6 inches; summer, 7.2; autumn, 5.2; winter, 2.6; year, 20.6. In the absence of any gaugings I estimate the discharge of the river as in the table below:

Estimated volume and horse-power of the Smoky Hill river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Below Saline river	11,641	190	216	270	307	380	432
Below Solomon river	18,859	380	432	530	602	720	818
At mouth	20,144	400	454	560	636	750	852

TRIBUTARIES OF THE SMOKY HILL.—In the lower course are received Lyon's, Chapman's, and Turkey creeks, all small streams, but used to a slight extent for power by flouring- and grist-mills. At Hays City, Big creek, which has a drainage area of 740 square miles, is improved for power by one mill; this obtains a head of 24 feet, and sufficient water to carry two runs of stone half the year. The only important tributaries of the Smoky Hill are the Solomon and the Saline.

The Solomon river.—Two forks, heading in the northwestern part of Kansas, unite in Mitchell county to form the Solomon river. The North Fork starts from the northeastern part of Thomas county, and makes a curve to the northward; it has a length by general course of 134 miles, and a drainage area of 2,631 square miles. The South Fork rises in the southwestern part of Thomas county, and pursues an easterly course. The length of this fork is 160 miles, and it drains 2,415 square miles. From the junction of these two forks the Solomon follows a southeasterly course for about 77 miles, till it empties into the Smoky Hill at Solomon City. It receives no important tributaries except the two forks already mentioned, and comprises within its basin 6,939 square miles.

Slope of the Solomon river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Kirwin, North Fork †	1,718	.....	.....	.....
Bulls City, South Fork †	1,673	91	19	4.79
Osborne, South Fork †	1,582	110	19	5.79
Cawker †	1,472	71	27	2.63
Beloit †	1,401	47	14	3.36
Brittsville †	1,354	104	27	3.85
Minneapolis ‡	1,250	84	35	2.40
Mouth of river §	1,166			

* Map measurement.
† Railroad levels, elevation of rails.
‡ Water surface in Pipe creek at railroad crossing.
§ Water surface at Union Pacific crossing.
NOTE.—Those slopes which are based upon comparisons of elevations of rails are obviously liable to some error.

In ascending the river the first improved power is at Bennington, where there is a three-run flouring-mill having a brush dam. The next power is at Minneapolis, county seat of Ottawa county, a place of some 1,100 inhabitants. The dam is of brush, and rests upon a sandstone bed; it has an artificial stone abutment at one end, and at the other abuts against a rocky bluff. In its construction a layer of trees, having their branches on, was first placed on the bed of the stream. The trees were laid side by side, parallel to the course of the stream, and were packed as closely together as possible, their buts pointing down stream. Upon this layer, which was perhaps 4 feet deep, a 4-foot layer of brush was added. An oak log was then placed on the brush, running transversely and several feet back from the ends of the trees, thus leaving their buts projecting a little way for an apron. Long spars, running up stream, were now dovetailed to the transverse log, and upon top of all loose rock was piled as

thickly as possible. There were then added successively a 4-foot layer of brush, a transverse log, and spars, as before. The top was next filled with rock to a regular incline, and planked over for a distance of 30 feet back from the crest.

The owner puts the cost of the structure at only $700. It was built in 1875, and is 160 feet long, with a fall of 8 feet; it stands well, and is reasonably tight. Before this dam was built a log dam was in use, but did not stand successfully. The pond extends 3 miles up stream. There is a head of 8 feet on the wheel, which gives power for three runs of stone. Water is brought to the wheel through a tunnel excavated in the rock, 80 feet long and 6 by 4 feet in cross-section. A separate tunnel, 1,000 feet long, conveys water to run two elevators (about 12,000 and 20,000 bushels capacity), and a pump for the railroad water-tank. There is always a surplus of water at this privilege, and for one to four weeks trouble is experienced from backwater. The owner estimates that with the present dam six runs of stone could be carried in the lowest stage of river.

The river in this part of its course is about 150 feet wide, with a depth varying from 4 feet at ordinary low water to 12 or 15 feet at high water. It has a moderate current and a steady flow. The period of high water extends from April to the 1st of August, the highest stage occurring for a few days during the heavy June rains. Once in a few years the main river overflows the bottoms in places, or else by its backwater compels the tributary creeks to run over their banks, in low spots, and so accomplish the same result. Owing to its tortuous course and rather moderate slope, local storms on the river above are not felt for some days at Minneapolis; and it is said to take one to two days for high water to extend from Delphos to that point, a distance of only 10 miles in a straight line.

The bed is mostly sand, but there are some riffles over rock ledges. The banks are of loam and are of fair height; at Minneapolis the river comes up to a bluff, and one bank rises abruptly 20 or 30 feet. The valley narrows at this point to 2 miles, but widens, a short distance below, to 4 miles. The bluffs probably average 125 feet in height above the river, though in places they almost disappear and there is seen only a wide level or gently inclined surface. The valley and surrounding country are good wheat and corn lands, the bottom being rather the best adapted to corn. There is an abundance of good building-stone, comprising magnesian limestone and sandstone, of red and darker shades. Along the main river and its small tributaries are found moderate amounts of timber—cottonwood, oak, elm, hackberry, and black walnut. There is a large amount of power still undeveloped on this part of the river. I was informed by Mr. Crosby, of Minneapolis, formerly county surveyor, that there are two good unimproved sites between Minneapolis and Delphos and one betwen Minneapolis and Bennington. There is a rock bed at all these places, and heads of 10 or 12 feet can be secured.

Above Minneapolis there are mills on the Solomon at Delphos, Brittsville, Asherville, Libertyville, Beloit, Solomon Rapids, Glen Elder, and Cawker. The dam at Beloit was built in 1875, and cost $5,000. It is about 200 feet long including abutments, 10 feet high, and consists of V-shaped bents of timber, joined by cross-timbers fitted or spiked to them, all crevices being filled with loose stone carefully rammed into place. The pond sets back 5 or 6 miles up stream. The mill has a head of 10 feet, six runs of stone, and uses about 80 horse-power. The river is in this locality about 150 feet wide, 6 inches deep at low water, and 16 to 18 feet deep at mean high water. It occasionally overflows its banks and runs a quarter of a mile in width. In very cold winters it freezes so thickly that the volume of running water is much reduced.

The current in this part of the river is rapid, and the flow comparatively steady from month to month. The bed contains frequent ledges of soft limestone. The banks are of loam, usually high on one side and rather low on the other. The bottom-lands display successive flood-plains, sometimes four in number, and are bordered by low bluffs. Wheat and corn are raised in this section, but the crops, especially of wheat, are rather poor from lack of rain. Good limestone occurs, and is largely employed in building. It is of a yellowish tint, is easily quarried with crow-bars in blocks 6 to 12 inches thick, and shows a dark band, 2 to 4 inches wide, of the color of iron-rust, running through the center of each layer. The dams in this section of the river are said to be generally of crib-work—logs laid with the stream, cross-logs jointed or bolted to them, and the spaces filled with stone and brush. They have commonly a fall of about 10 feet. There are several mills on the main river in Mitchell county, but there are also reported to be good sites still unimproved.

At Cawker, a short distance below the junction of the North and South Forks, there is a two-run flouring- and grist-mill, using a fall of 9 feet and 30 horse-power. The dam is leaky, but the owner thinks his privilege would carry one more run as it now stands, in the lowest stage of river. His dam is a timber structure, built in 1871, and is 150 feet long and 9 feet high. The pond sets back for 3 miles.

The only tributaries of the Solomon of any importance for power are the two forks already referred to.

The first mill met on the North Fork is about 3 miles above Cawker. The wheel is of 46 horse-power, and runs under a head of 10 feet. The mill carries three runs of stone and has a surplus of water at all times. The dam was built in 1878, and cost $1,600. It is 98 feet long, 10 feet high, and consists of a timber crib-work packed with stone. It backs the water for about 1½ miles. As nearly as I could ascertain at Cawker there are mills beyond at the following points: 15 miles above Cawker, one mill; 18 miles beyond Cawker, one mill; one mill at Harlan and one at Cedarville, each two runs; one at Kirwin, one at Logan, and another at an intermediate point, each of three runs. There are also one or two mills still farther up stream. These mills are said generally to have dams built of logs, with brush filling, and to obtain heads ranging from 10 to 20 feet.

This stream is said to have a fall in its upper waters of 6½ to 8 feet per mile, and it was stated to me that a good, available site for power, with rock bottom, could probably be found, on the average, once in 3 miles. The North Fork averages about 70 feet in width toward the mouth. Its bed is largely composed of sand and gravel, with frequent limestone and slaty ledges. Where the latter occur below a dam they are badly torn up by the overflowing water unless protected, as they usually are, by an apron. The river banks are frequently high on one side and low on the other. The banks, where low, are composed of loam, but, where high and bluffy, stone usually crops out. In this case the rock often appears to run out under the stream and then to suddenly drop away. At the mill 3 miles above Cawker the wheel rests upon a hard and firm clay bottom, but 6 inches away from the wheel-pit, toward the stream, there is a wall of slaty rock belonging to the bluff on the opposite side of the river. The owner of this privilege has noticed similar occurrences elsewhere along the stream. The slate rock has no value for building purposes, being soft and crumbly.

The South Fork is about 50 feet wide at Osborne. It has a rapid current, and comparatively steady flow from month to month, but is subject to rapid oscillations after heavy rains. The highest stage is usually in the first week of June, when the stream regularly overflows its banks and runs one-eighth of a mile in width in its lower course. The bed is mainly sand and gravel and shows very little rock. The banks are of sandy loam, averaging perhaps 6 feet in height. The bottom-land is 3 to 5 miles wide between bluffs, the latter ranging from 75 to 200 feet in height. Both the bottom-land and the surrounding country are claimed to have a fertile soil, best suited by nature to wheat; but, owing to the scarcity of rain, corn is the principal crop raised. There is very little timber, only 2 per cent. of Osborne county being thus covered, and that is found fringing the streams. Plenty of good magnesian limestone is to be obtained in the bluffs, easily quarried, sawed, and planed, but growing hard on exposure.

The lowest mill on the stream is at Osborne. It carries four runs of stone, has 12 feet head, and there is said to be in process of construction a substantial stone dam, to cost $4,000 to $5,000. Above Osborne there are reported to be two mills, of two runs each, at Bulls City, and another mill of the same size at Stockton. The dams are described as costing from $1,000 to $3,000 each, and built of crib-work filled with brush. They are said to rest upon poor foundations, to be loosely constructed, and to give considerable trouble.

Estimated volume and horse-power of the Solomon river and its tributaries.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
North Fork:	*Sq. miles.*						
At Logan	783	15	17	25	28	30	34
At Kirwin *	1,553	35	40	50	57	60	68
At Eagle Rapids	2,210	50	57	70	80	90	102
At mouth	2,631	60	68	80	91	110	125
South Fork:							
At Beech creek	738	15	17	25	28	30	34
At Stockton	1,582	35	40	50	57	60	68
At mouth	2,415	50	57	80	91	100	114
Solomon:							
At Cawker	5,046	120	136	160	182	210	239
At Beloit	5,545	140	159	190	216	240	273
At Minneapolis	6,150	160	182	220	250	280	318
At mouth	6,939	200	227	260	295	330	375

* Below Deer creek.

The Saline river.—The Saline river rises in Wallace county, in northwestern Kansas, and flows easterly, parallel to the Smoky Hill, into which it finally empties. Receiving no important tributaries, it drains a long and narrow strip, which, until the river has run half its course, does not exceed 18 miles in width. The stream is not touched by any railroad except at its mouth, but it is only 5 to 20 miles distant from the Kansas Pacific line throughout its course. There are no towns of importance on the river. The Saline is 220 miles long by general course, and drains 3,463 square miles.

The country along this stream is fertile, and produces good crops of wheat and corn, the bottoms being rather the best adapted to the latter crop. On that portion of the stream lying above Russell there is considerable timber, including cottonwood, elm, ash, box-elder, and some oak and hackberry. Light sandstone is found on the Saline north of Russell, east of that blue limestone, 6 miles east of the locality first mentioned hard iron-stone, and farther

down stream blue limestone again. In the middle course the valley is 1 mile to 2 miles wide, and bounded by bluffs 200 feet in height. Toward the mouth the width of the valley increases to from 3 to 3½ miles, and the soil is said to be very rich, better, in fact, than that along the Smoky Hill.

North of Russell the river falls 22 feet in 3½ miles; from Lincoln Centre to the mouth, a distance, by map measurement, of about 48 miles, a railroad survey shows an approximate fall of 152 feet, or 3.17 feet per mile. If the river were accurately measured through all its windings the distance would appear much greater, and the slope correspondingly less. Thus I was informed by Mr. Rossiter, civil engineer, who had just finished a survey bordering part of the river, that, running 16 miles northwest from Salina, in a comparatively straight line along the stream, the actual length of river, following all its bends, was 96 miles. North of Russell the Saline is about 25 feet wide at low water and 3 feet deep; in a high stage it is 130 feet wide and 8 feet deep. It has a strong current and a bed composed of firm sand to a depth of 2 feet, below which it is blue clay. The banks are of sandy loam, and average 8 feet in height. In its lower course the river continues narrow, and below Lincoln is frequently only 25 to 30 feet in width. The bed in this section, and for a considerable distance above, consists mainly of quicksand. The banks are abrupt and high, usually 30 to 35 feet above low water.

Toward the headwaters of the river there are numerous beautiful pools of water, containing 1 acre to 7 acres each. The stream continues fresh till about opposite Russell, where the drainage from salt springs and salt marshes renders its waters strongly saline. It is said to be subject to an unexplained swell, continuing from the first of February till the middle of April. It is claimed that there is not enough snow at the headwaters to cause this rise, which is announced by the banks becoming wet and marshy. Whether or not it is due to underground drainage remains to be determined. The Saline has a steady flow from month to month, and is not greatly affected by ordinary storms; still, the heavy summer rains do produce important oscillations in its volume, and at some points it overflows its banks for perhaps 50 yards on either side. In its upper and middle portions it has a strong current, but toward the mouth it grows sluggish, and its slow current and crooked course tend to hold back high water, so that the stream does not run out very quickly.

Notwithstanding its generally sandy bed, the Saline shows some rock ledges in its course, and because of its reliable flow is looked upon as a good mill-stream. There are plenty of sites still unimproved. Ascending the stream, there are flouring- and grist-mills at the following points: Windsor, Rocky Hill, Lincoln Centre, Sylvan Grove, Paradise, and Martin. They carry from two to three runs of stone each, have in most cases heads of 8 to 12 feet, and are seldom short of water.

Bradshaw's mill, in Paradise township, has three runs of stone, with sufficient power for five runs, except in very cold winters, when the stream freezes almost solid and there is scarcely power for a single run. The mill is located about midway across the neck of a loop or bend in the river, the distance around the bend being 3½ miles. A dam has been thrown across the stream on the upper side of the bend, and a race carried across the neck, thus taking advantage of the intervening fall. A total head of 22 feet is thus obtained. The dam rests upon a gravel bed, and is built of brush; it is 90 feet long, 6 feet high, and was constructed in 1879 at a cost of $200. The original dam was only 60 feet long, but the river washed across one end, and the present structure was made longer. The banks are rip-rapped to prevent scour. The dam throws the water back about 1½ miles up the river.

Estimated volume and horse-power of the Saline river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Martin	1,200	25	28	40	45	50	57
Lincoln	2,560	60	68	90	102	110	125
Mouth of river	3,463	100	114	130	148	160	182

Power used on the Kansas river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Horse-power of wheels.
						Feet.	
Kansas	Missouri	Kansas	Douglas	Flour and grist	4	Lawrence power, 8 feet head.	265
Do	do	do	do	Iron castings	1		30
Do	do	do	do	Woolen	1		10
Do	do	do	do	Wire	2		9
Do	do	do	do	Shirt-factory	1		3
					9	8	317
Big Stranger	Kansas	do	Leavenworth	Flour and grist	2	31	85
Delaware	do	do	Jefferson	do	5	46	300
Do	do	do	Atchison	do	2	18	77
Straight	Delaware	do	Jackson	do	1	.....	12
Cross	Kansas	do	Shawnee	do	1	9	24
Mill	do	do	Wabaunsee	do	2	17	60
Red Vermillion	do	do	Pottawatomie	do	2	20	56
Rock	do	do	do	do	1	22	60
Big Blue	do	do	do	do	2	17	85
Do	do	do	Marshall	do	1	Blue Rapids, head 8 to 11 feet.	105
Do	do	do	do	Paper	1		45
Do	do	do	do	Iron castings	1		12
Do	do	do	do	Plaster	1		30
Do	do	do	do	Woolen	1		125
Do	do	do	do	Saw	1	8	30
Do	do	do	do	Flour and grist	3	25	255
Do	do	Nebraska	Gage	do	4	32	255
Do	do	do	Saline	do	1	10	80
Fancy	Big Blue	Kansas	Riley	do	1	14	30
East Fork	do	do	Marshall	do	1	12	65
Little Blue	do	do	do	do	2	12½	175
Do	do	do	Washington	do	1	8	32
Do	do	Nebraska	Jefferson	do	3	23	140
Do	do	do	Thayer	do	2	13	85
Do	do	do	Nuckolls	do	2	15	116
Do	do	do	Clay	do	2	16	59
Do	do	do	Adams	do	1	16	30
Mill	Little Blue	Kansas	Washington	do	2	20	36
Rose	do	Nebraska	Jefferson	do	1	10	24
Do	do	do	Thayer	do	1	11	22
Spring brook	do	do	do	do	1	12	15
Big Sandy	do	do	do	do	1	8	60
Turkey	Big Blue	do	Saline	do	3	39	132
West Fork Blue	do	do	Seward	do	3	27	138
Do	do	do	Fillmore	do	1	11	48
Do	do	do	York	do	3	28	135
Do	do	do	Hamilton	do	1	14	19
North Fork Blue	do	do	Seward	do	3	25	212
Do	do	do	Butler	do	1	10	30
Lincoln	North Fork Blue	do	Seward	do	1	12	14
Do	do	do	York	do	1	12	20
Clark's creek	Kansas	Kansas	Davis	do	1	8	14
Smoky Hill	do	do	do	do	1	9	66
Do	do	do	Dickinson	do	2	18	222
Do	do	do	Saline	do	1	8	75
Do	do	do	McPherson	do	2	16½	44
Do	do	do	Russell	do	1	8	35
Lyon's creek	Smoky Hill	do	Dickinson	do	1	15	25
Chapman's creek	do	do	do	do	3	33	134
Turkey creek	do	do	do	do	1	9	35
Solomon	do	do	Ottawa	do	3	26	177
Do	do	do	Cloud	do	1	12	60
Do	do	do	Mitchell	Flour and grist (one saw)	7	60½	420
North Fork Solomon	Solomon	do	Smith	Flour and grist	2	23	75
Do	do	do	Phillips	do	3	29	112
Do	do	do	Norton	do	3	52	111
South Fork Solomon	do	do	Osborne	Flour and grist (and saw)	2	17	114
Saline	Smoky Hill	do	Lincoln	Flour and grist	4	42	127
Do	do	do	Russell	do	1	21	46
Do	do	do	Ellis	do	1	9	26
Big creek	do	do	do	do	1	18	36
Republican	Kansas	do	Clay	do	1	8	65
Do	do	do	Cloud	do	1	5	40

360

Power used on the Kansas river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Horse-power of wheels.
						Feet.	
Republican	Kansas	Kansas	Republic	Flour and grist	1	5	60
Do	do	Nebraska	Webster	Flour and grist (and saw)	1	5	75
Do	do	do	Franklin	Flour and grist	1	4	50
Do	do	do	Harlan	do	1	5	30
Do	do	do	Furnas	Saw	1	11	36
White Rock	Republican	Kansas	Republic	Flour and grist	1	10	30
Do	do	do	Jewell	Flour and grist (and saw)	1	12	50
Lost creek	do	Nebraska	Nuckolls	Flour and grist	1	13	65
Elm Creek	do	do	Webster	do	1	16	28
Turkey creek	do	do	Franklin	do	1	20	40
Thompson	do	do	do	do	2	26	90
Prairie Dog	do	do	Harlan	do	2	25	54
Do	do	do	do	Saw	1	12	30
Do	do	Kansas	Phillips	Flour and grist	1	12	35
Do	do	do	Norton	do	1	12	18
Do	do	do	do	Saw	1	10	15
Sappa	do	Nebraska	Harlan	Flour and grist	1	6	14
Do	do	Kansas	Norton	do	1	15	25
Beaver	Sappa	Nebraska	Furnas	do	1	15½	43
Muddy	Republican	do	do	Saw and grist	1	13	40
Medicine	do	do	do	Saw	1	8	24
SUMMARY.							
Kansas	Missouri	Kansas			9	8	317
Delaware	Kansas	do			7	64	377
Big Blue	do	Kansas and Nebraska.			16	103	1,022
Little Blue	Big Blue	do			13	103½	637
West Fork Blue	do	Nebraska			8	80	340
North Fork Blue	do	do			4	35	242
Smoky Hill	Kansas	Kansas			7	59½	442
Solomon	Smoky Hill	do			11	98½	657
North Fork Solomon	Solomon	do			8	104	298
South Fork Solomon	do	do			2	17	114
Saline	Smoky Hill	do			6	72	199
Republican	Kansas	Kansas and Nebraska.			7	43	356
Prairie Dog	Republican	do			6	71	152
Sundry small streams	Kansas and tributaries	do			41	486½	1,408
Total Kansas river and all tributaries.					145	1,345	6,561

THE LA MINE RIVER.

Below the Kansas the first river worthy of notice is the La Mine, which drains an area of 2,700 square miles, situated in the western central part of Missouri. It enters the Missouri river in Cooper county, a few miles above Boonville. Ascending the river, it is found to divide about 10 miles above the mouth, one fork coming in from the south; while from the west it receives the Black Fork, which rises in the western part of Johnson county, and has a length by general course of about 65 miles.

The country drained by the La Mine is a rolling prairie, with a fair amount of timber along the streams. It is a rich agricultural section, with valuable resources also in the way of building-stone, coal, lead, and other minerals. The stream was not visited by me, and detailed information cannot here be given regarding it. A small grist-mill, using 5 feet head, is returned as taking power from the La Mine, and one, with 6 feet head, from the Black Fork. If we may judge from other streams in this section, the La Mine would probably furnish small powers for the greater part of the year, but cannot be considered a stream of any especial value.

Drainage areas, La Mine river.

Stream and locality.	Drainage area.
	Sq. miles.
Black Fork, at Houstonia, Pettis county	986
Black Fork, at mouth	1,492
South Fork, above Black Fork	1,185
Total, La Mine below junction	2,677
Total, La Mine at mouth	2,700

MOREAU CREEK.

This creek may serve as an example of some of the smaller streams of central Missouri. Rising in Morgan county, it flows easterly through Moniteau and Cole counties, entering the Missouri a few miles above the mouth of the Osage. It well illustrates how winding are some of the rivers of this state; although its entire length, by general course, is only 30 to 35 miles, yet 30 miles of its actual course lies within 6 miles of Jefferson City. It drains 384 square miles of country, rich in resources. The valleys are valuable for agriculture; the surface is thickly timbered with oak, ash, elm, hickory, walnut, sycamore, and cottonwood; while bituminous and cannel coal, lead, iron, zinc, copper, and building-stone occur more and more abundantly toward the headwaters.

This region is very hilly and is intersected by numerous small streams which run into the Moreau. The fall of the latter is stated to be 2½ to 3 feet per mile. Owing to the limited extent of its drainage area, the stream would not, probably, furnish continuous power to any but small mills. A small grist-mill is returned as taking power from it, with 9 feet head, in Cole county, but otherwise it is unemployed. In consequence of its tortuous course, there are points at which power might be developed by tunneling through a neck of land at a long bend. Such a site has been described to me by Mr. George B. Ransom, surveyor of Cole county. It is close to Jefferson city, in sections 28 and 29, township 44, range 11, and offers a good location for a mill. Mr. Ransom carried a line of levels over the bluff at this point, and found a fall of over 20 feet in the intermediate portion of the river.

THE OSAGE RIVER.

Below the Kansas river, the most important tributary of the Missouri, so far as concerns extent of country drained, is the Osage. Occupying the intermediate space between the La Mine and Gasconade, it comprises within its basin a large and valuable section of southwestern Missouri and southeastern Kansas, having a superficial area of about 15,300 square miles. The eastern portion of this section has a diversified surface, varying from the level alluvial bottoms of the streams to broken, hilly uplands; it is covered with a thick growth of timber, including various kinds of oak, elm, walnut, maple, ash, and many other varieties of trees. West as far as the Sac river the appearance of the country remains substantially the same, gradually, however, assuming more of the prairie character, and the quantity of timber somewhat diminishing; advancing still nearer the western boundary of the state of Missouri, timber disappears from the uplands, though it is still seen in heavy fringes along the streams, the surface of the country becomes more gently undulating, and we are in the midst of broad prairies which extend unbroken to the Rocky mountains.

The resources of southwestern Missouri are magnificent in quality, variety, and extent, but, owing largely to sparse settlement and imperfect means of communication, they yet lie comparatively undeveloped. Doubtless the chief in importance are the valuable minerals scattered lavishly over this portion of the Osage basin. First in abundance is iron, said to occur in large quantities in nearly every county along the Osage, and especially in the counties of Miller, Camden, Morgan, and Benton. The varieties of ore are principally limonite, red hematite, and blue specular, and thousands of tons are stated to lie on the surface of the ground in the shape of large bowlders. Bituminous coal is found all along the river, and in Morgan and Benton counties there are beds of cannel-coal. Lead is also scattered through this section, and deposits of zinc, copper, nickel, cobalt, and tin exist. There is an abundance of limestone and sandstone, suited to building purposes, throughout this part of Missouri, and kaolin and grit occur in some of the counties as valuable deposits. The formations of coal, limestone, and sandstone are continued through that portion of the Osage basin which lies in Kansas, but the metals are confined to the extreme southeastern corner of that state.

Aside from its resources of minerals, timber, and stone, the section of country drained by the Osage is rich agriculturally. The gently-rolling prairies of the western half, and in the eastern half the valleys and river bottoms, are splendidly adapted to the raising of corn, wheat, oats, tobacco, and various other staples. The rich grasses, including in the south the blue-grass, the abundance of timber and the numerous springs and small running streams, offer great advantages for stock-raising. The climate is healthful, with usually mild winters and but a small amount of snow and ice.

The principal fork of the Osage rises in the prairies of eastern Kansas, some 30 miles southwest of Topeka, taking thence a southeasterly course into Missouri. The Little Osage rises farther south in Kansas, runs easterly, and about 20 miles east of the Missouri boundary joins the main river. The latter is locally known as the "Marais des Cygnes" above the mouth of the Little Osage, but on the maps the Osage is recognized as extending into Kansas, and I assume its head to be at Osawatomie (mouth of Pottawatomie creek), and consider its continuation above that point to be the Marais des Cygnes. In Missouri the Osage pursues a winding course, with a general direction somewhat north of east, and reaches the Missouri river about 10 miles east of Jefferson City.

The country drained by this river is fairly well supplied with railroad facilities on the north side and toward the headwaters, though the lines usually run at right angles to the river's course; but to the south, in Missouri, the nearest roads are 20 to 60 miles away from the main stream. Navigation commonly extends to Tuscumbia, about 60 miles by river from the mouth, above which point there is considerable rafting of railroad ties and lumber.

In spring high-water boats ascend to Osceola, 221 miles from the mouth, and have even gone as high as Papinsville. The river has been surveyed or reconnoitered by government engineers up to Ottawa, Kansas, with a view to its improvement for navigation. The only satisfactory method of improvement seems to be by a system of locks and dams, but the expense of such a work would be so great that it is not thought it would be warranted by the commerce of this section for many years to come.

As early as 1850 or 1855 attempts were made by the state of Missouri to improve the river, and wing-dams were built on many of the shoals; they were not well located or properly constructed, however, and failed in their purpose. Since 1870 appropriations of $20,000 to $25,000 have been made in various years by the general government, and work has been directed to the building of cross-dams and training-walls, the clearing of the channel by scraping at the shoals, and the removal of rocks, snags, and leaning timber, with the object of obtaining a 2-foot channel at lowest stage of river.

The Osage runs through an alluvial bottom, in which it winds along, approaching first one bluff and then the other. Following the general trend of its valley, and neglecting the minor bends, it measures about 280 miles in length to the head of the Marais des Cygnes, but its actual length is probably at least 500 miles. The bed is generally gravel, especially on the shoals, though considerable sand is found in the quiet pools, and appears to be everywhere underlaid by rock at a depth of 5 or 10 feet. The banks are gravelly and stable, and range for the most part from 20 to 25 feet in height above low water, sometimes rising to 35 feet, and again falling to 18 feet. At Papinsville the Osage is, in a low stage, but a small stream, with a few inches of running water on the shoals, though in great freshets it is 20 feet deep. For several miles below the mouth of the Little Osage the main river is 150 feet wide at low water, 5 feet deep, clear, and with no perceptible current. Below the mouth of the Sac the width between banks is 350 to 400 feet, and steadily increases to the mouth, where it is about 1,000 feet.

Although this river makes a show of some importance to the eye, it is really only a chain of deep pools, connected by shoals having moderate fall. The amount of water flowing at a low stage is small, but difficult to estimate on account of the gravelly bed, which permits considerable water to leach along through it. I am informed by Captain O. H. Ernst, corps of engineers, from whom most of my information concerning this river was obtained, that the low-water discharge at Tuscumbia and below is assumed at 300 cubic feet per second. In the upper portion of the main river the volume has been estimated as low as 56 cubic feet per second, but cannot be accurately stated for the reason already given. The shoals connecting the pools are natural dams, being accumulations of gravel, causing contraction of the water-way both vertically and horizontally. Although it might seem easy at first glance to remove these natural dams and secure navigation, yet if it were done the pools would be drained and the stream much diminished in size.

From the engineers' surveys the slope of the river is found to be as follows:

Slope of the Osage river.

Section of river.	Distance between points.	Fall between points.	Fall between points.
	Miles.	*Feet.*	*Ft. per mile.*
Ottawa, Kansas, to state line	90⅓	121.75	1.35
Thence to mouth of Little Osage	56	42.70	0.76
Thence to Osceola	49⅔	25.75	0.52
Thence to Rainy creek, in Camden county, Missouri	91	77.60	0.85
Thence to Tuscumbia	70½	65.00	0.92
Thence to mouth of Osage	59½	25.50	0.43
Total, Ottawa to mouth	417	358.30	0.86

Tuscumbia is just above the influence of backwater from the Missouri.

Although the Osage is but a small stream at low water, it becomes a mighty flood during freshets. It is subject to great and rapid rises, and also to long periods of drought. The highest recorded rise at the mouth is 39 feet, and was not due to backwater from the Missouri, which is itself sometimes set back by the Osage in very high water. In 1880 a gauge was established at Tuscumbia, some of the records of which are of interest as showing the character of the river. In August, 1880, the gauge stood at about zero, or low-water mark. Early in September it reached about 9 feet, the river rising 7 feet on September 3. October 1 the reading was 0.05 foot; October 10, 4.95 feet, and October 22, 0.50 foot. The stream remained low and frozen most of the time till the 7th of February, when it began to rise and broke up the ice. It rose nearly 15 feet in a few days, or from zero to 14.95 feet (February 10). April 1 it was down to 5 feet, and through that month gradually fell.

That portion of the river between Osceola, Missouri, and Ottawa, Kansas, has been surveyed and reported on by Colonel James H. Simpson, corps of engineers. (*a*) As before stated, the local name above the Little Osage is

a Report dated February 13, 1879; not published.

"Marais des Cygnes", meaning "seven marshes", and it is said that marshes seems an appropriate term to apply to the river at a low stage. The survey by Colonel Simpson was made in the dry season, when there was practically no water flowing, at least the velocity was so small that it could not be measured, and no instrumental gauging was attempted. The banks in this part of the river average 25 feet in height above low water. Occasional limestone or sandstone bluffs are met, varying from 40 to 200 feet in height, but always with an alluvial bottom opposite. Here, as well as in the lower river, the freshet rise is large. In the rise of 1875 the river above the Little Osage was unusually high; the height at Ottawa as 35 feet above low water, and at Papinsville, Missouri, it was 25 feet.

There is one dam on the Marais des Cygnes and there are three on the Osage, located as follows: Franklin county, Kansas, one with 8 feet fall; Day's dam in Miami county, 8.2 feet fall; Trading Post dam in Linn county, 5 feet fall; Haymaker's dam in Bates county, Missouri, 8.6 feet fall. From what has been said, I think it is evident that the main river has practically little or no value for water-power. The only points in its favor are a firm bed and high banks. On the other side are to be placed its width, its extremely small volume at certain seasons, and its liability to sudden and very heavy rises, which must, at times, submerge its banks. It has scarcely any current at a low stage, its fall is slight, and there would be great trouble to mills from backwater. The country through which it runs is sparsely settled, and there are no important towns on its course. Roscoe, Osceola, and Warsaw enjoy a small local trade, but the latter place, the largest of the three, returns only about 500 inhabitants.

Concerning the tributaries of the Osage I have but little information, but they are undoubtedly much better suited to use for water-power than the main river. Most of them must run very low at times, but for the greater part of the year they could probably be relied upon for moderate powers. The Sac is one of the most important of these. It joins the main river from the south, a short distance above Osceola, and is said to have nearly as large a low-water discharge as the Osage at their junction. It is used for power by a considerable number of small flouring- and grist-mills, more than are found on any other tributary of the Osage.

The Niangua is another important branch, and is well sustained by springs. Concerning one of these it is said: (*a*) "No water-power can excel that at Bryce's spring, on the Niangua. It discharges about 11,000,000 cubic feet of water per diem, with no perceptible variation of temperature or quality." Its temperature is about 60° Fahrenheit; no ice ever forms, and the flow is very steady. The Gravois and Pomme de Terre are also used for power, but are of less importance than the Sac and Niangua.

The average rainfall on the Osage basin is, approximately, 12 inches in spring, 14 in summer, 9 in autumn, 6 in winter, and 41 for the year. The yearly amount shows great fluctuations in the upper basin and its vicinity, ranging, in a term of years, from 29 to 63 inches at Fort Scott, and from 38 to 88 at Olathe, Johnson county, Kansas. The volumes assumed for a low stage by the government engineers correspond to a rate of discharge varying from less than 0.01 cubic foot per second per square mile of drainage area, for the upper river, to about 0.02 foot for the lower. This rate of discharge is very small, being not more than one-sixth the low-water rate of the Gasconade to the east; and, in fact, probably no greater than for the James river, of Dakota, where the annual rainfall is less than half as large as here. It must be explained, I think, by the occurrence of long periods of drought; by the great evaporation consequent upon the open, prairie character of the country toward the headwaters, and the long, winding course and sluggish flow of the river; and, perhaps, by unusually large loss from percolation through the underlying formations and deposits.

Estimated volume and horse-power of the Osage river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Below Little Osage	5,631	70	80	140	159	270	307
Below Sac	8,348	120	136	210	239	420	477
Baker	8,632	120	136	220	250	440	500
Warsaw	11,732	210	239	330	375	650	738
Linn creek	13,382	260	295	370	420	740	841
Tuscumbia	14,286	300	341	410	466	830	943
Mouth of river	15,262	300	341	460	523	920	1,045

NOTE.—Drainage area of the Marais des Cygnes at Ottawa, 1,253 square miles; Osage at La Cygne, 2,769 square miles; Little Osage, 1,723 square miles; Sac, 1,932 square miles; Pomme de Terre, 980 square miles; Grand, 1,940 square miles; Niangua, 1,011 square miles.

364 *a* Barnes' *Commonwealth of Missouri.*

Power used on the Osage river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Auglaize	Osage	Missouri	Miller	Flour and grist	1	4	8
Do	do	do	Camden	do	2	20	29
Wet Auglaize	Auglaize	do	do	do	1	6	19
Do	do	do	Miller	Woolen	1	5	8
Small streams	Niangua	do	Camden	Flour and grist	3	61	46
Do	do	do	Laclede	do	1	20	200
Do	do	do	Dallas	do	3	49	43
Do	do	do	do	Saw	1	4	20
Pomme de Terre	Osage	do	Benton	Flour, grist, and saw	1	7	56
Do	do	do	Polk	Flour and grist	1	6	20
Do	do	do	do	Saw	1	10	60
Sac	do	do	Saint Clair	Flour and grist	1	7	20
Do	do	do	Cedar	do	1	8	20
Do	do	do	Dade	do	1	6	82
Small streams	Sac	do	Cedar	do	1	.....	34
Do	do	do	Polk	do	1	8	45
Do	do	do	Dade	do	3	24	98
Do	do	do	do	Flour, grist, and saw	1	6½	22
Do	do	do	Lawrence	Flour and grist	4	70½	75
Do	do	do	Greene	do	8	109½	131
Osage	Missouri	do	Bates		1	9	.....
Do	do	Kansas	Linn	Flour and grist	1	5	25
Do	do	do	Miami		1	8	.....
Marais des Cygnes	Osage	do	Franklin	Flour and grist	1	8	50
Small streams	do	Missouri	Miller	do	1	20	16
Do	do	do	Morgan	do	2	45	28
Do	do	do	do	Woolen	3	56	26
Do	do	do	do	Flour, grist, and saw	3	47	58
Do	do	do	do	Saw	1	5	10
Do	do	do	Benton	Flour and grist	1	16	8
Do	do	do	Henry	do	1	7	12
Do	do	Kansas	Miami	do	1	9	20
Do	do	do	Linn	do	3	58	43
Do	do	do	Anderson	Saw	1	6	15
SUMMARY.							
Osage	Missouri	Kansas and Missouri.		Flour and grist	3	22	25
Auglaize and tributaries	Osage	Missouri		do	5	35	64
Small streams	Niangua	do		Flour and grist (1 saw-mill).	8	134	309
Pomme de Terre	Osage	do		Flour, grist, and saw	3	23	136
Sac and tributaries	do	do		Flour and grist (1 saw-mill).	21	239½	527
Small streams	do	Missouri and Kansas.			18	277	286
Total, Osage and tributaries.					58	730½	1,347

THE GASCONADE RIVER.

Piney, Lick, and Osage forks, heading in southern Missouri, come to a final union in Pulaski county, where they make up the main Gasconade river, which then pursues a northeasterly direction to the Missouri. From the junction of the forks to the mouth the distance by general course is about 60 miles, but accurately measured is probably twice as great. The basin of the river comprises a total area of 3,667 square miles. The country along its course is sparsely settled by a thrifty class of German farmers; but there are no important towns, and the combined population of those counties, from Pulaski down, which touch the stream directly, is only about 30,000. The Missouri Pacific railway crosses the river near its mouth, and a few miles below the mouth of Piney Fork there is a crossing of the Saint Louis and San Francisco line, but the intermediate section is without railroad facilities.

The country lying at the headwaters of the Gasconade is, to a considerable extent, an elevated table-land belonging to the Ozark range of hills, and has an elevation of 1,200 to 1,500 feet above the sea. It has an irregular surface, which becomes very rough and broken along the streams. The latter are kept steadily supplied by a great number of springs, many of which are of large size, and are used for power to a small extent by flouring- and grist-mills. They are bordered by alluvial bottom-land, varying in width from a few hundred feet to half a mile, and very productive. The soil of the bottom-land and of much of the upland in this part of Missouri yields good crops of corn, wheat, rye, oats, and tobacco. The ridges are covered with a thick growth of oak, while in the valleys there are extensive tracts of pine, and a variety of other trees, including ash, sycamore, cottonwood, elm, hickory,

walnut, and maple. The country is well supplied with limestone and sandstone, and has valuable mineral resources of lead, iron, and zinc. The abundance of nutritious grasses, timber, and clear water renders it very favorable to stock-raising.

Under the direction of Major Suter, the Gasconade has been examined and reported upon by Mr. Thomas Y. Johnston, assistant engineer, to whom I am indebted for much information concerning the stream. The examination extended over that portion between the mouth and Indian Ford, near Vienna, and was made with a view to improving the navigation. From the report (*a*) it appears that at present there is no navigation, though with a moderate rise boats are enabled to ascend as far as the Saint Louis and San Francisco railway crossing. An active business is done in rafting lumber and ties, and it is estimated that 80,000 of the latter were floated down in 1879. From Indian Ford to the mouth, a distance of 78¼ miles, there is a fall of 108 feet, or about 1.4 feet per mile. The river is a succession of pools and shoals, with a mean channel width at low water of about 200 feet. The chief hinderances to navigation were found to be an insufficient depth of water on the shoals, and the presence of snags at various points. It was proposed to remove the latter, and to rectify and deepen the channel by the construction of low dikes, the estimated expense of the work being $50,000. In June, 1880, $5,000 was appropriated by Congress for the removal of snags.

The valley of the stream averages about half a mile in width, and is bordered by bluffs 100 to 200 feet high. The bed is usually gravel on the shoals, with considerable sand and mud in the pools, and is underlaid by rock at an estimated depth of 10 to 30 feet. The banks are about 20 feet high on the lower river, and show a deposit of alluvial soil, with sand and gravel underneath. The rock occurring along the stream is mainly limestone and sandstone. The Gasconade is subject to sudden and great spring freshets. In the portion surveyed the ordinary oscillation is stated as 15 feet, with a maximum of 23 or 24 feet. At Rolla it was said that in its upper course the river rises 20 feet or more above low water, sometimes coming up 7 or 8 feet in a single day. In very high water it overflows the banks and submerges the valley from bluff to bluff, though such a stage lasts but a short time.

The river is almost entirely unused for power. On the upper course a flouring- and grist-mill is returned for Pulaski county, having 9 feet head and 18 horse-power. Below Vienna there is a small saw- and grist-mill at a locality known as Prior's Bend, and situated on a slough. By tunneling, at a point above the mill, from the upper side of the bend, across the neck to the head of a small creek which puts into the river, a fall of 8.25 feet can be obtained. At Powell's mill, not now in use, there is a dam and some four feet fall. On the portion of the river that has been surveyed the shoals have but a slight declivity, and with the exception of Prior's Bend the maximum fall on any one is only 3 feet. In its upper waters the Gasconade is a much more rapid stream; in the vicinity of Waynesville it is 300 feet wide, with shoals every quarter or half mile. The bed is of rock and gravel, and the banks usually rise in rocky cliffs on one side, with a strip of sand or rich loam on the opposite shore; the freshet rise is about 6 feet. The river is in this section very winding, and forms numerous long bends with narrow necks. One of these bends, located in section 9, township 36, range 12, is said to be 15 miles in length, though the distance across the neck is not more than a quarter of a mile. The intervening fall is estimated to be at least 75 feet.

The volume of the Gasconade at extreme low water, below Vienna, is given by Mr. Johnston as about 450 cubic feet per second, equivalent to 0.14 cubic foot per second per square mile of drainage area. I quote from a letter by that gentleman, giving valuable information regarding the discharge and oscillations of the river:

The discharge of the Gasconade river at any point is derived from two sources—one the surface drainage, the other the subsurface drainage. The smallest value of the latter constitutes the low-water discharge (loss by evaporation and seepage not being considered), since at time of lowest water there is no surface drainage. As to the volume of this subsurface drainage, the smallest in the lower river has alone been measured, and amounts to 450 cubic feet per second; nothing is known as to what its maximum volume may be, except what is embodied in the assertion that the subsurface drainage increases to some extent after rains and melting of snows, in a way varying with the duration, amount, and extent of these phenomena. The amount of water derived from this source diminishes, of course, as one ascends the river; however, in low water, in the lower hundred miles of the river, it is very probable that, in consequence of evaporation and seepage, this diminution of discharge in ascending the river is changed to a diminution of discharge in descending. This is because at time of low water there is scarcely any subsurface drainage in the lower part of the river valley.

The component of the discharge derived from surface drainage exists only at times when the river is above low water—at times of rains and melting of snows. When obtained from heavy rains of short duration the water passes off very rapidly, owing to the steep slopes of the tributaries; so rapidly, in fact, that the river will rise as much as 10 feet in twenty-four hours. When derived from slow, protracted rains, or melting of snows, the water passes off nearly as rapidly, but the supply being slow and protracted the river will rise more slowly and less high, and the rise last longer. Should a protracted dry season have preceded the rains, a considerable volume of water will be at first absorbed by the ground; a part of which augments subsurface drainage, and the rest is evaporated.

The extreme range between high and low water in the Gasconade varies from 20 to 25 feet, according to the physical features of the river bed where the oscillation is measured. The discharge corresponding to highest water is roughly estimated at about 35,000 or 40,000 cubic feet per second. The total annual discharge of the river varies largely from year to year; also the length of time during which the river can be found at any given stage varies very much. Thus in a year of frequent and slow rains, while the river never attains a great height, still it remains above ordinary low water all the year; the stream would, of course, oscillate in unison with the variation in frequency and amount of rains; such a season occurs once in a while. Going to the other extreme, very heavy rains may occur early in the spring, after which the river rises very high, and then rapidly recedes toward low water, and remains in that vicinity all the rest of the year, very low water probably existing late in the fall; such seasons occur occasionally. All grades exist of variations of method of discharge between these extremes, the tendency being primarily toward high waters early in the spring, and secondarily in the late fall, with low stages intervening. Considerable rises about May are not infrequent. The lowest water almost always occurs in the fall of

a See *Report Chief of Engineers for* 1880.

the year—usually in late October or November. This is rational in consideration of the fact that surface drainage almost always amounts to nothing in the fall, and consequently subsurface drainage tends to exhaust itself. It is in virtue of the subsurface drainage that the river does not run dry, the resistance to draining rainfall by subsurface channels being great, and hence protracting the drainage. The same cause tends to preserve the constancy of low-water discharge.

It appears to me that the surface drainage operates against milling interests for several reasons, at least. Its amount and time of duration and occurrence cannot be relied upon. If a dam is used to gain the head of water (its height being limited on account of prevailing overflow), that head diminishes as the river rises in such a way that at high water, if the dam is in height but half that of the normal oscillation of the river, the head will be nearly obliterated. If lateral canals are used for gaining head of water they will have to be several in number at different levels, or else one very expensive deep one with at least one high artificial bank, with sluices at either end extending above high water. If tunneling through the hills across the neck of a bend in the river is resorted to the most favorable plan for using volume of surface drainage is adopted; but the first objection still holds—unreliability of surface drainage.

On the other hand, subsurface drainage appears to be the most useful for milling purposes. Its volume and variation in volume approach nearer to constancy, and, I think, are capable of being approximately determined, if the necessary physical features of the stream in question are observed. As to the Gasconade river no observations have been made that point to determining any other feature of this subsurface drainage than its minimum amount, 450 cubic feet per second. That this minimum amount *sometimes* lasts several months in the year is tolerably certain, and that during the rest of the year it is more. That this minimum amount is sometimes *not* reached at all during a whole year is quite certain. But nothing is known as to the average annual duration of it, and consequently and similarly nothing is known of the average duration of higher stages of the river.

From what has been said it is evident that the Gasconade might be made to yield important powers, although works designed for that purpose would need to be substantial and expensive. In its favor are to be mentioned the firm gravelly bed; banks of moderate height, though usually lower on one side than the other; and a well-sustained and considerable low-water volume. The railroad facilities, however, are not good at present; the greater part of the main river presents no shoals of importance; and the valley is often badly overflowed. The large amount of rafting done on the stream would also threaten injury to dams. It was stated to me that the owners of saw-mills in this section regard the use of the river for water-power as practicable, but consider that it would be too expensive for their business, and prefer to employ portable engines. Probably the forks which go to make up the Gasconade would be found better suited to development than the main river.

The rainfall on the basin of this river is, approximately, 12 inches in spring, 11 in summer, 8 in autumn, 7 in winter, and 38 for the year. I estimate the volume and horse-power as in the table below:

Estimated volume and horse-power, Gasconade river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Osage Fork, above Lick Fork	649	60	68	110	125	160	182
Lick Fork, above Osage Fork	744	70	80	130	148	180	204
Total below junction	1,393	130	148	240	273	340	386
Above Piney Fork	1,915	260	295	340	386	470	534
Piney Fork	752	70	80	130	148	180	204
Total below Piney Fork	2,667	330	375	470	534	650	738
At Vienna	3,181	430	488	560	636	780	886
At mouth	3,667	450	511	650	738	900	1,022

Power utilized on the Gasconade river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Gasconade	Missouri	Missouri	Osage	Flour and grist	1	4½	68
Do	do	do	Pulaski	do	1	9	18
Piney Fork	Gasconade	do	Texas	do	3	25	35
Do	do	do	do	Saw	1	4	10
Do	do	do	do	Woolen	1	5	6
Small streams	Piney Fork	do	Pulaski	Flour and grist	2	60½	51
Do	do	do	Phelps	do	3	30½	40
Do	do	do	Texas	do	2	44	26
Lick Fork	Gasconade	do	Wright	do	1	7	8
Wood's Fork	Lick Fork	do	do	do	1	4	6
Osage Fork	Gasconade	do	Laclede	do	3	13	34
Spring	do	do	Maries	Woolen	1	14½	35
Do	do	do	do	Flour and grist	3	32	49
Total					23	253	386

Summary of power utilized on the tributaries of the Missouri river.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Sundry streams	Missouri	Montana territory			24	715½	654
Do	do	Wyoming territory.			2	25	38
Small streams	do	Dakota territory			4	51	127
Dakota	do	do			6	47½	228
Vermilion	do	do			5	35	133
Big Sioux and tributaries	do	Dakota territory (mainly).			16	159½	673
Floyd	do	Iowa			2	22	61
Little Sioux and tributaries	do	do			21	213½	907
Soldier	do	do			2	13	57
Boyer and tributaries	do	do			9	79½	242
Platte and tributaries	do	Nebraska and Colorado.			84	1,069½	4,157
Little Nemaha	do	Nebraska			9	99	228
Small streams	do	Iowa			7	82	234
Do	do	Nebraska			21	293½	622
Nemaha and tributaries	do	Nebraska (mainly)			14	150½	464
Nishnabatona and tributaries	do	Iowa (mainly)			23	219	764
Big Tarkio and tributaries	do	Missouri and Iowa			5	46	133
Nodaway and tributaries	do	do			18	159	449
Platte and tributaries	do	do			23	202	869
Kansas and tributaries	do	Kansas and Nebraska.			145	1,345	6,561
Grand and tributaries	do	Missouri and Iowa			37	290	1,063
Chariton and tributaries	do	do			6	50	215
Osage and tributaries	do	Missouri and Kansas.			58	730½	1,347
Gasconade and tributaries	do	Missouri			23	253	386
Small streams	do	Kansas			1	15	50
Do	do	Missouri			16	218½	350
Total for the Missouri river basin.					581	6,584	21,012

V.—THE EASTERN IOWA SLOPE.

The section thus designated lies east of the water-shed line, which, passing southerly through Iowa, divides the basin of the Mississippi from that of the Missouri. The principal streams are as follows:

	Square miles.
Maquoketa river, drainage area	1,921
Wapsipinicon river, drainage area	2,568
Iowa river, drainage area	12,519
Skunk river, drainage area	4,409
Des Moines river, drainage area	14,578
Total	35,995

I omit from this list the Turkey and Upper Iowa rivers, which properly belong to eastern Iowa, but were not within the district assigned to me for examination.

The Upper Des Moines and Cedar rivers drain limited areas in southern Minnesota, and the lower valley of the Des Moines includes a narrow strip in northeastern Missouri; otherwise the basins of the streams to be considered are within the state of Iowa. The surface is usually an undulating prairie, but in some localities, as to the west of Fort Dodge, closely approaches a level; there is only a small percentage of timber, and that exists mainly as fringes along the water-courses. Scattered over the upper basins of the rivers are many natural ponds of small size, and occasionally there is a lake of several square miles area. As shown by the courses of the streams, the country has a general declivity to the southeast; from Spirit lake, in the northwest, to the mouth of the Des Moines, the average amount of this declivity is 4½ feet per mile. The mean elevation of the surface may be taken as 900 to 1,000 feet above sea-level, the altitude of various points being shown in the accompanying table·

Altitude of points on the eastern Iowa slope.

Locality.	Elevation above sea.	Authority and remarks.
"Great" water-shed:	*Feet.*	
Spirit lake, high ground near	1,722	*Geology of Iowa.*
Summit between Raccoon and Little Sioux rivers	1,486	*Geology of Iowa.* Illinois Central railroad levels.
Tip-top station, Chicago and Northwestern railway	1,441	*Geology of Iowa.* Chicago and Northwestern railway levels.
Summit of Great water-shed	1,451	*Geology of Iowa.* From levels Chicago, Rock Island and Pacific railway.
Intermediate:		
Cedar Rapids	721	*Geology of Iowa.* Water surface at Chicago and Northwestern railway crossing.
Marshalltown	910	*Geology of Iowa.* Rails Chicago and Northwestern railway.
Des Moines	786	Water surface by old survey.
Fort Dodge	1,537	Water surface at Illinois Central railroad crossing.
Mississippi river:		
Mouth of Maquoketa river	572	Levels of Major Farquhar, connecting with Lake Michigan.
Mouth of Wapsipinicon river	559	Do.
Mouth of Iowa river	522	Do.
Mouth of Skunk river	505	Do.
Mouth of Des Moines river	476	Do.

NOTE.—Elevations from the *Geology of Iowa* have been corrected to make planes of reference agree in elevation with more recent determinations.

The soil is of Drift formation and is very productive, yielding largely in corn, wheat, grass, and oats. According to the *Iowa Agricultural Report* for 1879, about 40 per cent. of the entire surface of the state was estimated to be still uncultivated. This percentage would be exceeded, however, in the northern and northwestern portions of the state, where the soil is somewhat less fertile than elsewhere, and settlement less dense. The Drift, which constitutes the principal surface deposit throughout eastern Iowa, is generally very thick. At many points it attains a depth of 100 feet, and is even 150 to 200 feet thick along the Great water-shed which separates the basins of the Mississippi and Missouri rivers. But along the course of the Shell Rock river, in northern Iowa, the deposit is said to be comparatively thin. The material of the Drift in Iowa is usually composed of the finer constituents, and therefore offers no serious hindrance to agriculture; it has an important influence upon the streams, inasmuch as it is well supplied with springs, which contribute to the steadiness of their flow. There is, in the latter respect, a marked contrast to the western Iowa slope, where the Loess is entirely lacking in springs.

Beneath the surface deposit of Drift are found the various rock formations, all stratified, and composed mainly of limestones. They are either horizontal or inclined at a very slight angle toward the south. They are frequently exposed in the beds of the streams, but do not create either abrupt falls or rapids of more than moderate pitch. Bituminous coal is found throughout the lower basin of the Des Moines, and at various points east and north valuable quarries of limestone suitable for building have been opened.

In the section under consideration the prevailing winds of the year are westerly, coming from the northwest in winter, and from the southwest, the rainy quarter, in summer. In the latter season violent wind-storms, and even tornadoes, are not uncommon. The summer rainfall is also sometimes excessively great. Thus, according to the Signal Service observations at Des Moines, the rainfall in June, 1881, was 15.79 inches, or considerably more than the usual amount for the entire summer. The average annual amount of snow in the southeastern part of the state is 33 inches.

Rainfall and temperature, eastern Iowa slope.

[From Smithsonian records.]

Locality.	Latitude.	Longitude.	Years of observation.	Spring.	Summer.	Autumn.	Winter.	Year.
RAINFALL.	° ′	° ′		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Fort Dodge	42 31	94 12	4	7.98	12.63	6.15	3.14	29.90
Des Moines	41 36	93 38	4	5.13	13.16	7.93	3.16	29.38
Independence	42 29	91 57	8	8.58	12.69	6.98	4.05	32.30
Iowa City	41 37	91 30	15	10.67	14.41	11.16	5.54	41.78
Dubuque	42 30	90 40	23	8.12	11.73	8.74	5.07	33.66
Keokuk	40 25	91 21	4	9.18	16.49	8.97	8.60	43.24
TEMPERATURE.				°	°	°	°	°
Port Dodge	42 31	94 12	4	42.57	73.04	49.16	18.97	45.94
Des Moines	41 36	93 38	4	49.99	71.80	48.59	25.39	48.94
Independence	42 29	91 57	7	43.98	70.48	47.51	19.18	45.29
Iowa City	41 37	91 30	12	46.23	71.25	49.62	22.69	47.45
Dubuque	42 30	90 40	19	47.33	71.71	49.16	22.55	47.69
Keokuk	40 25	91 21	2	50.09	74.77	54.05	29.37	52.07

The streams which are to be described already furnish power to a large aggregate number of flouring- and grist mills, and at a few points on the Cedar, Iowa, and Des Moines manufacturing centers of some prominence have been developed. A large amount of fall is still unimproved, however, but will doubtless be taken up with the growth of the country in population and wealth. The Des Moines river in particular, from its size and the favorable character of its bed, offers facilities for water-power improvements on an important scale. None of these rivers are navigable, but the Mississippi river, on the east, and a network of well-equipped railway lines, furnish easy means of communication with all important markets and sources of supply. Corn, wheat, and wool are close at hand; iron, lead, and zinc are easily obtained in Missouri, to the south, and lumber is to be had from the north.

The rivers of eastern Iowa are characterized by gentle currents and a usually well-sustained flow. The beds are muddy in some sections, but are more commonly of gravel, and display numerous exposures of rock. The banks are of moderate height, and are occasionally submerged during freshets. High water occurs during spring and early summer, and is followed by a falling stage, with a minimum in late summer, fall, or, during a severe winter, in the latter season.

In the absence of all records whatever of gaugings upon any of these streams, I have been compelled to rely upon my own estimates of their volume in order to form some idea of the amount of power they are capable of furnishing. In making these estimates I have been largely guided by a comparison with three other streams—the upper Mississippi, the Minnesota, and the Illinois, the volumes of which, as determined by government engineers, are given below. So far as possible, I have also taken into account the individual features of each river.

Low-water volumes of the Mississippi, Minnesota, and Illinois rivers.

[Drainage areas of the Mississippi and Illinois are as measured by Mr. James L. Greenleaf.]

River and locality.	Rainfall on tributary area (approximate.)					Drainage area.	Volume, cubic feet per second.	Cubic feet per second per square mile.	Authority and remarks.
	Spring.	Summer.	Autumn.	Winter.	Year.				
MISSISSIPPI.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*			
Frenchman's Bar	6	12	6	3	27	35,824	5,000	0.140	The upper basin, above latitude 44° to 45°, is thickly wooded and contains many lakes and swamps. The volumes here given are those adopted for low-water discharge in the government survey. With regard to the low-water line determined by that survey it is stated that "extreme low water occurring during the winter or from ice gorges has not been considered in determining the low-water line as not influencing navigation". (See report by Captain A. Mackenzie, corps of engineers, pages 1517 and 1519 *Report Chief of Engineers for* 1880.)
Wabasha	6½	12	7	3	28½	* 55,876	10,000	0.179	
Winona	6½	12	7	3	28½	† 59,256	11,000	0.186	
Johnsonsport	.....	.....	.....	.....	.....	.....	14,000	.....	
Below Wisconsin river	7	12	7	3½	29½	78,565	17,000	0.216	
Lyons	7	12	7½	3½	30	‡ 84,857	18,500	0.218	
Princeton	7	12	7½	3½	30	‡ 87,558	19,000	0.217	
Rock Island	7	12	7½	3½	30	87,842	19,000	0.216	
Burlington	7½	12	7½	4	31	113,495	22,000	0.194	
Canton	7½	12	8	4	31½	133,995	26,000	0.194	
Hannibal	7½	12	8	4	31½	137,460	30,000	0.218	
MINNESOTA.									
Foot Big Stone lake	6½	12	5	3	26½	920	11	0.012	Volumes as given in report by General G. K. Warren, corps of engineers. (See appendix J, *Report Chief of Engineers*, 1875.) These volumes were given as the lowest that had been observed, but the river may have been even lower at other times. The basin of the Minnesota contains a considerable number of small lakes and ponds, and a few with areas of 5 to 10 square miles or even more. The country is thickly timbered below Judson and Mankato, but is an open prairie above.
Above Pomme de Terre creek	6½	12	5	3	26½	2,620	42	0.016	
Above Redwood river	6½	11	5	3	25½	8,540	217	0.025	
Fort Ridgeley	6½	11	5	3	25½	9,850	253	0.026	
Above Big Cottonwood river	6½	11	5	3	25½	10,190	307	0.030	
Judson	6½	11	5	3	25½	11,940	397	0.033	
Belle Plaine	6½	11	5½	3	26	16,380	1,575	0.096	
Above Little Rapids §	6½	11	5½	3	26	16,660	1,924	0.115	
Mouth of river	6½	11	5½	3	26	17,230	‖ 1,155	0.067	
ILLINOIS.¶									
At mouth	11½	11	9	8	39½	29,013	1,600	0.055	Extreme low water as given by Major G. J. Lydecker, corps of engineers. Basin is a rather flat prairie, swampy toward the headwaters.
At mouth	11½	11	9	8	39½	29,013	1,750	0.060	Ordinary low water as given by Major Lydecker.

* Mouth Chippewa river.

† Mouth Trempealeau river.

‡ Approximate.

§ Thirty miles from the mouth.

‖ Observed November 25, 1867.

¶ Concerning this stream Major Lydecker says: "The Illinois river is a very flat stream, and is fed mainly by the rainfall on a prairie country; the bottom-lands adjoining its bed are low, and cut up by numerous lagoons or lakes that hold the water back. Excepting in times of freshet, or after a long period of heavy rains when the bottoms are full, the water of rainfalls is slow to reach the stream, and correspondingly sluggish in its movement to the mouth. Again, the water that finds its way into the river above the dams at Copperas creek and Henry (by which slack-water is created on its upper portion) is held back in the pools created by these dams * * * ". The average slope toward the mouth is about 0 15 foot per mile.

Assumed rates of discharge for the eastern Iowa rivers.

Stream and locality.	Rainfall (approximate).					Drainage area.	Assumed discharge in cubic feet per second per square mile.			Remarks.
	Spring.	Summer.	Autumn.	Winter.	Year.		Low-water, ordinarily dry year.	Low-water, average year.	Available ten months in average year.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*				
Maquoketa, at mouth	10	12	8½	4½	35	1,921	0.094	0.114	0.172	Basin is rolling prairie, covered with Drift. Frequent rock exposures.
Wapsipinicon, at mouth	8½	12	9½	6	36	2,568	0.093	0.117	0.175	Drains rolling prairie covered with Drift. Frequent rock exposures.
Cedar, at mouth	9½	13½	8½	4½	36	7,715	0.096	0.119	0.175	Largely fed by springs. Drift is shallow in upper basin, and rock frequently exposed.
Iowa, above Cedar	10	13½	11	6	40½	4,467	0.092	0.107	0.175	Rolling prairie with Drift. Frequent rock exposures.
Skunk, at mouth	9	14	9½	4	36½	4,409	0.061	0.082	0.120	Rolling prairie covered with Drift. Not much rock exposed, except in lower course. Stream said to be unreliable.
Des Moines, at mouth	8½	13½	9	4	35	14,578	0.078	0.090	0.135	Upper basin slightly undulating; Drift soil of considerable depth, much less cultivated as yet than in the eastern part of the state; very little timber, but region well supplied with springs.

VI.—RIVERS OF THE EASTERN IOWA SLOPE.

THE MAQUOKETA RIVER.

The Maquoketa is the first and most easterly of the streams which I shall consider. It rises in Fayette county, 30 to 35 miles west of the Mississippi, runs southeasterly, and empties into the latter river in Jackson county, approximately midway between Clinton and Dubuque. It is 95 miles long by general course, and drains 1,921 square miles. This section is underlaid by Niagara limestone, valuable quarries of which have been opened at Farley, on the Illinois Central railroad. The rough weathering of this stone has given the valley of the river quite a wild and romantic appearance in places. The valley is not deep, however, being seldom depressed as much as 200 feet below the general level of the surrounding uplands, to which there is usually a gentle rise.

Elevations on the Maquoketa river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft per mile.*
Manchester†	905	333	87	3.83
Mouth of river‡	572			

* Map measurement.
† Low water at Illinois Central railroad crossing.
‡ Low water in Mississippi river, by levels of Major Farquhar, connecting with lake Superior.

The Maquoketa is said to be a good stream for milling, and is so employed to a moderate extent by flouring and grist-mills, a summary of which is given in a subsequent table. The railroad facilities are good, and below Manchester the stream is at no point distant more than 7 miles from some line, and is crossed at several localities. The principal towns are Maquoketa, population about 2,500; Monticello, 1,900, and Manchester, 2,300.

Estimated volume and horse-power of the Maquoketa river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
At Delhi	386	30	34	40	45	60	68
At Monticello	642	50	57	70	80	110	125
At Maquoketa, above North Fork	995	90	102	120	136	170	193
At mouth	1,921	180	204	220	250	330	375
North Fork, at mouth	530	40	45	70	80	100	114

THE WAPSIPINICON RIVER.

This river lies next south of the Maquoketa, and is remarkable for its long and narrow drainage basin. The latter contains an area of 2,568 square miles, and is 185 miles long; yet its width is only 10 to 20 miles, till, within a short distance of the mouth, it widens out to 25 miles. Draining so narrow a strip, it receives no important tributaries, and is probably subject to less rapid rise and fall than it would be if the area were more extended, since, during a generally-prevailing storm, its accessions are not concentrated, but quite uniformly distributed over the whole course. Still the Wapsipinicon is liable to important oscillations, and during the heavy rains of June overflows its banks, in the lower course at least, though not commonly to a dangerous extent.

The source of this stream is in southeastern Minnesota, only a few miles above the Iowa boundary; entering Iowa, it runs southeasterly and joins the Mississippi 10 miles southwest of Clinton. The upper basin is underlaid by the Devonian formation, but below Buchanan county the course of the river is over the Niagara limestone. The valley is, in general features, like the valleys of the Cedar and Maquoketa rivers, which adjoin it on either side. In the vicinity of Anamosa it is quite narrow and picturesque; the bed and banks are rocky, the latter rising to a good height and frequently running abruptly up into bluffs.

The Wapsipinicon is a good milling stream; its firm banks, and the frequent exposures of rock in its bed, are favorable to dams, and the flow is quite steady and well sustained. This part of Iowa is well supplied with railroads, but above Anamosa they usually cross the basin of the river at a large angle, and do not, therefore, give as good facilities as are enjoyed by the lower river, where the immediate valley is followed more closely. The principal towns are New Hampton, population about 1,100, near the upper waters; Independence, 3,700, on the middle course; and Anamosa, 2,100, some 40 miles, by general course, farther down.

The slope of the stream is approximately as follows:

Slope of the Wapsipinicon river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Independence †	887	198	95	2.08
Near Wheatland ‡	689			
Mouth of river §	559	130	40	3.25

* Map measurement.
† Low water at Illinois Central railroad crossing.
‡ Water surface at Chicago and Northwestern railway crossing.
§ Low water in Mississippi river, by levels of Major Farquhar, connecting with lake Superior.

The use of this river for power is confined almost entirely to flouring- and grist-mills, of which a considerable number are scattered along its course. The highest privilege in use is said to be employed by a little saw-mill near the Minnesota line. Between that point and Independence there are flouring-mills at Martinsburg, Tripoli, Chatham, and possibly at one or two other places.

At Independence the river is 150 to 200 feet wide, with banks 6 to 10 feet high. The Independence flouring-mill is one of the largest on the river; it has 9 feet head, and uses 100 horse-power. The dam is leaky, yet only in very dry seasons is any trouble experienced from low water. The owner of the privilege thinks that with a tight dam it is good for 200 horse-power eight months in the year, and for 100 horse-power practically all the time. I estimate the power as below:

Estimate of power at Independence.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 9 feet head.
	Sq. miles.		
Low water, ordinarily dry year	1,056	90	92
Low water, average year		110	112
Available 10 months in average year		160	164

Below Independence there are reported to be 8 flouring-mills on the Wapsipinicon, most of which carry three runs of stone each. The dams are of varied construction, brush, framed, or stone, according to the local character of the river bed. They have stood well in most cases, the chief trouble being from ice; freshets, and, in two or three instances, undermining, have also wrought injury.

Near Anamosa there are valuable quarries of magnesian limestone. The river is about 150 feet wide in that section, and has a good current. Doane's flouring-mill at Anamosa has 7 feet head, carries three runs of stone, and is able to run at full capacity throughout the year. The proprietor thinks the privilege would carry six runs of stone in an ordinary low stage of water. Very little hindrance, lasting not more than a few days, is experienced from backwater. The dam is an old structure, part crib-work and part brush, the whole ballasted with stone. It is about 200 feet long, 7 feet high, and rests upon a rock ledge; one end abuts upon a rocky bank and the other upon a masonry abutment.

Estimated volume and horse-power of the Wapsipinicon river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Tripoli	371	20	23	40	45	50	57
Independence	1,056	90	102	110	125	160	182
Anamosa	1,560	140	159	180	204	260	295
Toronto	1,861	170	193	210	239	310	352
Mouth of river	2,568	240	273	300	341	450	511

THE IOWA RIVER.

The Iowa and its tributary, the Cedar, are by far the most important streams in Iowa so far as regards the extent of their employment for power. The former drains 4,467 square miles above its junction with the Cedar, while the basin of the latter measures, down to the same point, 7,715 square miles. The Cedar is, therefore, much the larger of the two; nevertheless, below their junction the main river takes on the name of the smaller stream, and is called the Iowa. (*a*)

This river rises in Hancock county, in northern Iowa, and flowing southeasterly enters the Mississippi in Louisa county. Its course is quite crooked, and disregarding the minor curves measures about 215 miles in length from source to mouth. Its own basin varies from 12 to 35 miles in width, being rather narrow above Marshalltown, while below that point it broadens out. The country is well cultivated, and has a comparatively thick settlement. The more important towns on the river, with their populations in round numbers, are as follows, beginning at the mouth: Wapello, 900; Columbus Junction, 800; Iowa City, 7,100; Marengo, 1,700; Tama, 1,300; Toledo (3 miles from the river), 1,000; Marshalltown (near river), 6,200; Eldora, 1,600, and Iowa Falls, 1,000. The river is crossed at frequent intervals by railways, and, except at the extreme headwaters, is nowhere distant more than a few miles from some established line.

As stated by Dr. White, the Iowa rises "in the midst of a broad, flat or slightly undulating Drift region. The first rock exposed in its valley is the sub-Carboniferous limestone, which occurs in the form of rocky banks to the stream in the southwestern corner of Franklin county. The river then enters Hardin county, and cuts across the northeastern corner of the Iowa coal-field in a southeasterly direction, and enters the region of the sub-Carboniferous

a Above its junction with the Mississippi, the total drainage area of the Iowa river and its tributaries is 12,519 square miles.

limestone again, which it crosses, continuing in the same direction, and enters the region of the Devonian strata near the southwestern corner of Benton county. It continues in the region occupied by the Devonian rocks all the way to its confluence with the Cedar."

The bottom-land bordering the stream varies greatly in width. At Iowa Falls, on the upper river, the valley sides close in, and there is scarcely any bottom. The bed and banks are there rocky, though muddy in the neighboring sections above and below. From Iowa Falls to Eldora, 14 miles by straight course down the river, the banks are generally low. The river is about 100 feet wide at Marshalltown, and 300 feet wide at Iowa City. From Tama to the latter point the valley is generally narrow, with bluffy sides, but widens out at Coralville, just above Iowa City. Over the section just mentioned the bed is usually rocky. The Drift which covers this region is well supplied with springs, and these give the river quite a steady flow and sustain it during droughts. It nevertheless happens once in two or three years that, during an uncommonly dry season or severe winter, the supply of water is greatly curtailed and the river runs low. The bottom-land is occasionally submerged during the high water of spring or early summer; a freshet rise of 10 feet has been observed at Iowa Falls, and a rise of 14 feet at Marshalltown. At the latter point the Iowa formerly overflowed the bottoms every year, but was reported not to have done so for three or four years previous to 1881. For the short period of extreme high water the mills on the river are hindered by backwater.

Slope of the Iowa river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Iowa Falls*	1,007			
		162	65	2.49
Near Montour†	845			
		238	90	2.64
Iowa City‡	607			
		85	60	1.42
Mouth of river §	522			

* Low water at Illinois Central railroad crossing.
† Water surface at Chicago and Northwestern railway crossing.
‡ From *Geology of Iowa.* Bed at Chicago, Rock Island and Pacific railway crossing.
§ Low water in Mississippi river, by levels of Major Farquhar, connecting with lake Superior.

Far the largest employment of power on this river is by flouring-mills; still, at such points as Tama, Amana, and Coralville are to be found numerous concerns, of moderate size, devoted to various branches of general manufacturing.

In Louisa county, on the lower river, there is a single flouring-mill, using 9 feet head and 85 horse-power. Above this point there is no use of power until Iowa City is reached, where Dietz & Hemmer have a flouring-mill, with a log dam and about 4 feet fall.

The next improved privilege is at Coralville, a mile or two above Iowa City, and is owned by Mr. M. T. Close. The dam was built in 1868, is 300 feet long, 9 feet high, and has rock abutments. The bed is rock half-way across the stream and quicksand the remainder of the distance. The dam is a framed structure, with four sets of braces, and is ballasted with stone; it is provided with an apron of crib-work, planked over. A head of 9 to 11 feet is obtained, and the following mills are supplied with power: (*a*) One paper-mill, manufacturing wrapping-paper and straw-board, and using say 250 horse-power; one flouring-mill, with four runs of stone and 50 horse-power; one oatmeal-factory, with 60 horse-power, and a capacity of 2,500 bushels of oats per day.

Once in two or three years the river runs very low, and the mills are then liable to be short of water for perhaps two months; but ordinarily the supply is abundant, and more power could be furnished than is now used. Trouble is experienced with backwater for two to four weeks in the year.

Estimate of power at Coralville.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 9 feet head.
	Sq. miles.			
Low water, ordinarily dry year	3,188	290	32.9	296
Low water, average year		350	39.8	358
Available ten months in average year		560	63.6	572

a The horse-powers given are the estimated amounts actually employed; the rated capacities of the wheels are considerably greater, and are, in the aggregate, 696 horse-power at this privilege. The paper-mill also employs 200 horse-power of steam as supplementary.

The next power employed is at Homestead, on the Chicago, Rock Island and Pacific railway, 18 miles northwesterly from Iowa City, and is owned by the Amana Society. Water is brought 7 miles, through a canal 65 feet wide, and supplies mills located at distances of 5 and 7 miles, respectively, from the head, with power as follows:

	Horse-power.
One starch-factory, 8 feet fall	40
One woolen-mill, 8 feet fall	40
One saw-mill, 8 feet fall	40
One woolen-mill, 12 feet fall	65
One grist-mill, 12 feet fall	110
One saw-mill, 10 feet fall	40
Total (*a*)	335

Water is diverted into the canal by a dam at the head, built of brush and stone. It is 220 feet long, 4½ feet high, and was constructed in 1868. The privilege is considered to be good for 300 effective horse-power, even in cold winters when the ice is very thick. By methods previously explained, I estimate the power as below:

Estimated power of Iowa river at Homestead.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 12 feet head.
	Sq. miles.			
Low water, ordinarily dry year	2,900	270	30.7	368
Low water, average year		320	36.4	437
Available ten months in average year		510	57.9	695

At Marengo there is a brush dam 5 feet high, from which water is carried, through a canal three-quarters of a mile, to a flouring-mill of three or four runs. There is no other improved site below Tama. At that place several establishments are supplied with power, water being brought 3¾ miles through a canal 30 feet wide and 3 feet deep. At the head of the canal is a dam, which was built in 1880 at a cost of $2,000 to $3,000. It is 300 feet long, 3 to 4 feet high, and rests upon a bed of quicksand, which by actual sounding has been found to be 50 feet deep. For a foundation, rows of piling were driven and filled in with brush. On this substructure rests the dam, which is a framed structure filled in with stone. The apron is built of logs, resting upon the same foundation as the dam, and having a slight upward slope away from the latter. The canal, or race, which conveys water to the mills, is provided, at a distance of a quarter of a mile from the dam, with a heavy timber guard-lock. It also has waste-gates where it crosses Deer creek. It enlarges at one point to a reservoir of 20 acres, and ends in another of 60 acres having a maximum depth of 14 feet. A head of about 22 feet is available at the mills, though at the time of my visit only 14 feet was being used. There are six establishments, none of more than moderate size, and devoted, respectively, to the manufacture of flour, paper, sash and blinds, agricultural implements, tubs, and wind-mills. About 128 horse-power is in use altogether, and in the dryest seasons there is a large surplus of power. It is said that the privilege has been estimated to have a capacity of 600 horse-power in the lowest stage of water. I could learn of no regular charge for power; the flouring-mill pays $1,200 per annum for 40 horse-power, with the privilege of using it 24 hours in the day, the water-wheel being furnished by the lessor.

The enterprise was started about the year 1875, and has had an unfortunate history. Owing to the scour of water below the dam the old structure fell in with almost yearly regularity, and then had to be repaired, either in whole or in part. This was not only a source of expense, but it tended to frighten manufacturers from going there to locate. The race banks were not given a sufficiently flat slope to prevent them from washing, and the wooden flumes at the end of the race are said not to have been properly constructed. The development of the power is reported to have cost in all over $100,000. The original company failed, and the privilege came into the hands of Mr. Purley Starr, of Brattleboro', Vermont, who still held it at the time of my visit, but, as I was informed, would like to sell for $35,000, the amount of his claim. A citizen of Tama has offered to build a dam, and to guarantee, with proper security, that it shall stand. The present dam, which I have already described, is considered safe, however. There is a considerable amount of surplus power to let, but no efforts are made to induce the establishment of new concerns. The privilege is very conveniently situated, the mills being but a little way from the Chicago and Northwestern railroad. It is stated that they have no trouble from backwater, and on that account are able to run when most other mills on the stream are stopped.

a Amount actually used estimated at 270 horse-power.

Estimated power of Iowa river at Tama.

Stage of river.	Drainage area.	Volume in cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 10 feet head.	Theoretical horse-power, 22 feet head.
	Sq. miles.				
Low water, ordinarily dry year	1,963	170	19.3	193	425
Low water, average year		200	22.7	227	499
Available ten months in average year		320	36.4	364	801

There are two other flouring-mills on the river in Tama county besides the one mentioned at Tama City. Proceeding up stream and entering Marshall county, we find mills at Le Grand, Quarry, and Marshalltown. At the latter point the valley is perhaps a mile wide, and the river itself measures about 100 feet across. Power is used at Marshalltown by the Woodbury mills (flouring). The dam was built in 1877, and cost about $1,300. It is 144 feet long, 6 feet high, and is a framed structure, resting upon a rock ledge and provided with an apron of crib-work ballasted with stone. The water is set back up the river a distance of 2½ to 3 miles. The mill carries five runs of stone, and uses 75 horse-power, under a head of about 6 feet. No trouble is experienced from low water, although there is not much surplus in that stage. Backwater causes hindrance for from two to six weeks in the year, and the difficulty is aggravated by the formation of gorges when the ice breaks up in the spring.

Advancing up the river from Marshalltown the remaining mills are located, in order, as nearly as I can ascertain, as follows: One at Union, one at Xenia, one at Eldora of three runs, one at Steamboat Rock of three runs, one at Eagle City, two at Iowa Falls, two at Alden Rapids, one at Alden, one at Belmond, and one on the upper waters in Hancock county. All these are flouring-mills, except the lower one at Iowa Falls, which is a small woolen-mill.

The upper privilege at Iowa Falls is owned by Messrs. Woods & Wright, and employed to furnish power to a flouring-mill with three runs of stone. The present dam was built about the year 1868, and is 130 feet long, with a height of 14 feet above the river bed. In its construction heavy timbers, say 30 feet long, were laid on the rock bottom in the direction of the stream, and at intervals of 10 feet. Each was pinned to the rock at three points by 1¼-inch iron pins. The dam was then carried up as a crib-work, securely fastened together with iron pins and carefully packed with stone. By building up the face faster than the back the requisite slope was given to the top of the dam, which measures 25 feet from the crest to the end of the back slope, and is heavily planked. At each end is a stone abutment, protected below the dam by piling. The structure has answered its purpose finely. Before it was built three framed dams had been carried out by ice; in one case the timber braces projected too far in front of the dam, and, though 12 inches square, were snapped in two by heavy cakes of ice falling over the crest. The mill-pond sets back one mile above the dam. There is a head of 10½ feet on the wheels, which are of 35 horse-power (total). Occasionally, in a severe winter, the mill has been short of water, but this is said to have happened only twice in twenty years, and on the average there is 6 inches of water running to waste over the dam. Mr. Wright thinks the privilege would carry considerable additional machinery three-quarters of the year.

Of the minor tributaries of the Iowa, English river is the most important. It heads in Poweshiek county, whence it flows easterly to the main river, with a length, by general course, of about 65 miles. Its drainage area is 657 square miles. It decreases quite rapidly in size above the mouth, but is described as a good stream for powers of moderate amount. There are three flouring-mills on its course in Washington county, and three in Iowa county. Bear creek, which enters the Iowa from the west at Marengo, is a much smaller stream than English river, but furnishes power to two small flouring- and grist-mills.

I am unable to give the locations of available sites for power, still unimproved, on the Iowa river, though numerous ones doubtless exist. Of the entire fall of 485 feet between Iowa Falls and the mouth, only about 160 feet, or 33 per cent., is at present improved. The following table is a summary of the estimated power of the river at different points in its course:

Estimated volume and horse-power of the Iowa river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Iowa Falls	660	50	57	60	68	110	125
Marshalltown	1,449	110	125	150	170	240	273
Tama	1,936	170	193	200	227	320	364
Marengo	2,823	260	295	310	352	500	568
Homestead	2,900	270	307	320	364	510	579
Iowa City	3,290	300	341	360	409	580	659
Above English river	4,204	390	443	470	534	750	852
Above Cedar river	4,467	410	466	480	545	780	886
English river	657	60	68	80	91	120	136

THE CEDAR RIVER. (*a*)

This important stream has its sources in southeastern Minnesota, in Dodge and Freeborn counties, 20 to 25 miles above the northern boundary of Iowa; entering the latter state it runs southeasterly till, in Louisa county, it joins the Iowa river, of which it is the principal branch. It has a length, by general course, of about 220 miles, and a drainage area of 7,715 square miles. The surface of the country is a gently undulating prairie, apparently level in some sections, with a moderate amount of timber in the form of groves or fringes along the streams. Peat beds and marshes are found in the northern counties, and there are a few lakes, of which the more important are Clear lake, in Cerro Gordo county, Iowa, having an area of 8 or 10 square miles; and Geneva, Rice, Freeborn, and Albert Lea lakes, in Freeborn county, Minnesota, containing 2 to 5 square miles each. The upper basin of the river has a width of about 50 miles; the lower basin is much narrower, however, and below Cedar Rapids, in southeastern Linn county, measures only 8 or 9 miles across. The principal tributary streams, in order from the mouth, are Wolf creek, Black Hawk creek, Beaver creek, Shell Rock river, and Little Cedar river; of these the Shell Rock, with a drainage area of 2,631 square miles, is much the largest.

The section drained by the Cedar has a Drift soil, largely a sandy or gravelly loam. It is very fertile, and, as a rule, yields well in corn, wheat, and other grains. Stock is also largely raised. Wheat has been the main production in the upper basin, but it is said that frequent failures of the crop there of late years have led the farmers to turn their attention to flax. The country is well settled, the entire population of the Cedar River basin having been estimated at 374,587 in 1880, an increase of over 83,000 since 1870. The larger towns on the course of the river in Iowa, from the mouth up stream, are Cedar Rapids, population about 10,000; Vinton, 2,900; La Porte, 1,000; Waterloo, 5,600; Cedar Falls, 3,000; Waverly, 2,300; Nashua, 1,100; Charles City, 2,400; and Osage, 2,000. This region is intersected by numerous and well-appointed railroads. The Cedar river is nowhere distant more than 6 miles from some line, and much of the way, especially in the upper half of its course, is closely skirted.

The entire course of the river is over the firm, compact limestone of the Devonian formation. This stream and its tributuries are stated by Dr. White to have more numerous and extensive exposures of rock along their valley than either the Iowa, Skunk, or Des Moines; the exposures usually appear as rocky banks to the streams, sometimes as cliffs rising 20 to 30 feet above them. The fall of the stream I am now describing is moderate, but it derives much value for power from the favorable character of its bed and banks, and its considerable and well-sustained volume. The rock exposures appear to be most numerous in the upper half of its course, and are to be accounted for in part by the hardness of the formation to which they belong; and also by the thinness of the overlying Drift in the upper basin, rendering it an easy task for the streams to cut their way down to rock. Although the river-bed contains so much rock, it is explained by Dr. White that, in consequence of its course coinciding closely with the general trend of the Devonian formation, it meets with little obstruction from them, and no falls or rapids of importance are formed.

The comparatively steady flow of the river is doubtless due to the general character of its basin. The Drift of Iowa is naturally well supplied with springs, and thus we find many spring-brooks feeding the upper Cedar; the country is well settled, and the ground has been, to a considerable extent, broken up for agriculture and rendered receptive of water; and, again, the slight depth of the Drift allows the water soon to find its way to the underlying rock, whence much is shed into the water-courses without sinking to lower depths. Still, it must not be supposed that the Cedar is free from considerable oscillations, for it is certainly true that during an unusually dry summer or severe winter its volume becomes much reduced. High water commonly occurs in June, but at Charles City, in the upper waters, the rise does not exceed 4 feet.

The valleys of this river and its tributaries are rather narrow in the upper basin, with gently sloping sides; but below the mouth of the Shell Rock the valley of the main stream becomes, and remains, broad and shallow in appearance, the borders which separate it from the uplands being indistinctly defined. The width of the river increases from 150 or 200 feet at Charles City, to 400 or 500 feet at Cedar Falls, and about 600 feet at Cedar Rapids. Its slope is given approximately in the following table:

Elevations and slope of the Cedar river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Cedar Falls†	845			
		124	73	1.70
Cedar Rapids‡	721			
		112	47	2.38
Moscow§	609			
		87	56	1.55
Mouth of Iowa river‖	522			

* Map measurement.
† River surface by Cedar Falls and Minnesota railroad levels.
‡ River surface by Chicago and Northwestern railway levels.
§ River surface at Chicago, Rock Island and Pacific railway crossing.
‖ Low water in Mississippi, by levels of Major Farquhar, connecting with lake Superior.

NOTE.—The elevations at Cedar Falls, Cedar Rapids, and Moscow are taken from *Geology of Iowa*, but with altitudes of datum planes corrected to agree with recent determinations.

a Also called Red Cedar river. Details given of improved powers on this river are as gathered by Mr. James L. Greenleaf, special agent.

The developed powers on the Cedar river are almost entirely devoted to the manufacture of flour, although at one or two principal points other branches of manufacturing are represented to a small extent. The lowest mill on the river is at Moscow, near the crossing of the Chicago, Rock Island and Pacific railway, in northern Muscatine county; it carries about three runs of stone, and has a cheap brush dam, yielding a head of 4½ feet. Between this point and Waterloo, in Black Hawk county, the only important improved power is at Cedar Rapids. There are two flouring-mills at other localities in Linn county and one or two in Black Hawk county, but from Waterloo to the mouth the river is claimed to be, generally speaking, poorly adapted to improvement, on account of its slight fall, width, and the lack of suitable sites. At Cedar Bluff, however, situated in the western part of Cedar county, 24 miles southeast of Cedar Rapids, there is said to be a very good location for developing a power, where, by backing the river up 10 or 12 miles, and building some side dikes to prevent overflow, a head of 10 feet may be obtained. The privilege is considered a valuable one, and the improvement of it has already been discussed somewhat. At present it suffers the disadvantage of having no established railroad less than 6 miles away. Cedar Bluff is a small village, with only about 100 inhabitants.

Cedar Rapids is an important city of 10,000 inhabitants, and the intersecting point of several prominent railway lines; it lies in the midst of a well-settled and fertile agricultural section. The Cedar river is there 500 to 600 feet wide, with low, gently-sloping banks, and a rocky bed, over which it runs in rapids. A framed dam of timber extends at right angles across the river, and forms a pond reaching 4 or 5 miles up stream, and partly covering the rapids. From either abutment a wooden guard-wall runs 75 or 100 feet along the side of the corresponding race. The race on the right-hand side of the river is short, and conveys water to a small foundery and machine shop using 20 horse-power; power has also been used on that side by an establishment for the manufacture of sash, doors, and blinds, but it has recently been washed away (previous to June, 1881), together with the adjacent guard-wall, thus causing a break through which the water pours, but which will doubtless be repaired.

On the left-hand side of the river is the principal employment of power. A race 35 feet wide conducts water to three flouring-mills and an oatmeal-mill, which was not, however, in operation when visited. These mills are located in a group along the race, and obtain a head ranging usually from 6 to 7 feet; it is even 8 feet at times, being highest when there is a fair stage of water in the river. In severe winters the flow of the stream is much diminished, but it is only in extraordinary seasons that the mills at Cedar Rapids are troubled by lack of water. There is, undoubtedly, a considerable waste of water at all times by leakage through various parts of the works. Difficulty on account of backwater is experienced usually for two or three days in spring, but the hindrance occurs only in high stages, and is of short duration, as the water is quickly carried off by the rapids below the dam. The ordinary freshet rise at the dam is said to be 4 or 5 feet above the average stage.

In the summer of 1880 a total of about 415 horse-power (*a*) was employed at this point. The available power is variously estimated at from 900 to 2,200 horse-power, with 7 feet head, in a low stage. It is certain that there is, under all ordinary circumstances, an important surplus power. By extending the race, and locating mills farther down stream, the head might be increased to perhaps 10 or 12 feet, advantage thus being taken of the rapids below the dam; but as the city is now built up the work of prolonging the race would be expensive. The entire power is considered as divided into sixty-four equal shares; the title to five of these is recognized by all parties as established, but that to the remaining shares is in dispute and litigation.

Estimate of power at Cedar rapids.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 7 feet head.	Theoretical horse-power, 10 feet head.
	Sq. miles.				
Low water, ordinarily dry year.....	6,543	640	72.7	509	727
Low water, average year		800	90.9	636	909
Available ten months in average year.		1,180	134	938	1,340

The next important power is at Waterloo, near the center of Black Hawk county. The neighboring country is rolling, and in many places covered with groves. The river is 500 to 600 feet wide, with banks 5 to 10 feet high. A timber dam about 550 feet long extends across the river at this point and sets it back, so that, in high stages, some difficulty is experienced from the backwater, at Cedar Falls, 7 or 8 miles above. The power at Waterloo is divided into twenty-four equal shares, of which twenty-three are owned by the Union Mill Company, and one by Messrs. Daniel & Slade. The Union Mill Company has a flouring-mill on each side of the river, using together about 300 horse-power. On the west bank Daniel & Slade's chair-factory employs a small power. On the same side a sash- and door-factory and a small woolen-mill use, respectively, 25 and 35 horse-power, which they rent from the Union Mill Company. An establishment for the manufacture of bee-hives is also returned as using 21 horse-power. Altogether about 400 horse-power is employed at this privilege. The ordinary working head is 5 feet.

a Rated power of wheels according to census enumerators' returns.

The mills are troubled by backwater a day or two in June, and in extremely cold winters are sometimes short of water. The dam is leaky, however, and it is thought that with a tight dam no difficulty would occur from low water. Commonly there is a large surplus power, which the proprietors are willing to rent. Waterloo has between 5,000 and 6,000 inhabitants, and is well situated, at the intersection of the Illinois Central and Burlington, Cedar Rapids and Northern railways.

Estimate of power at Waterloo.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 5 feet head.
	Sq. miles.			
Low water, ordinarily dry year	5,177	510	57.9	290
Low water, average year		630	71.6	358
Available ten months in average year		930	105.6	528

In the winter of 1881–'82 articles of incorporation were filed by the Waterloo Water-Power Company, with a capital of $300,000. This company proposed to develop a power in the south part of the city by throwing a dam across the river about 3,400 feet below the one I have described. From this dam a race, 100 feet wide, was designed to run 2 miles across a neck of land, emptying into the Cedar river again and rendering available a head of 7 feet. I have no further particulars concerning this enterprise, except that it was stated that work would probably be begun in the spring of 1882.

The first power above Waterloo is at Cedar Falls. The river is in that section 400 to 500 feet wide, with rather low banks. It makes a gradual bend to the eastward past the town, and on the upper part of this bend is the dam, a framed structure of timber resting on a rock bed. From the dam, the main race runs on the right-hand side of the river across the bend. Along this race, and on the side which is toward the river, are located a pump manufactory and an oatmeal-mill, in the same building, a woolen-mill (not running when visited), and a flouring-mill. The head increases from 5 feet at the dam to 8 or 9 feet at the lower mills. The dam sets the water back 3 miles up the river. The entrance to the main race is controlled by 12 gates, each about 5 feet wide, raised or lowered by levers. This race is, at the head, 70 feet wide and 4 or 5 feet deep; it continues of quite uniform width to the lower end, where it broadens to 150 feet.

The main race terminates in a timber dam 50 feet long, with abutments. From the right end of this dam a wooden flume conveys water some 30 feet to a bulkhead, surmounted by a tower, and containing 3 water-wheels. The power developed by these is transmitted distances of 50 to 200 feet, and runs a wagon-shop, foundery, and feed-mill. The main race is also continued in a smaller race, which carries water to a flouring-mill and novelty works (wood working); a second flouring-mill was burned, though the walls are still standing.

The power at this point is, with one or two minor exceptions, owned by the individuals using it, who are not incorporated, but merely united in an association in order better to maintain the works. Their rights are estimated in square inches of opening, under an average head of 9 feet. The various concerns own from 100 to 1,500 square inches each, or a total of about 6,000 square inches, which is considered to be the available capacity of the privilege in a low stage, with the present improvements. A total of about 490 horse-power is used here; it is claimed, however, that with proper improvements, and the use of the full head of 9 feet, the power can be doubled. There is abundance of room along the race for building, but the race itself is rather shallow, and by the formation of thick ice in winter the flow through it is much impeded. The dam is leaky, and by the cutting of a high-water channel around its end, on the left shore, where the land is low, a passage has resulted through which there is also at low water an important waste, thus lowering the head at the mills. Even under these circumstances they suffer very little from low water. In severe winters the supply sometimes decreases so that they have to compromise with each other, but such occurrences are rare. The working head varies about 1 foot, being highest in a fair stage of river. No serious trouble is experienced from backwater.

Estimate of power at Cedar Falls.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 9 feet head.
	Sq. miles.			
Low water, ordinarily dry year	4,726	460	52.2	470
Low water, average year		580	65.9	593
Available ten months in average year		850	96.6	869

There are no large developed powers above Cedar Falls, but there are numerous flouring-mills, the locations of all but one or two of which are herewith given, in order: Janesville, Waverly (two mills), Pearl Rock, Nashua, Charles City, Floyd, Osage, Mitchell, West Mitchell (woolen-mill), Saint Ansgar, Newburg, Otranto Station, and Otranto. All these are below the Minnesota boundary. They carry from three to seven runs of stone each, and have heads ranging from 5 to 10 feet, the average being 7½ feet.

At Charles City the river is 200 feet wide, and a framed dam of timber filled with stone has been built across it, creating a head of 10 feet. The privilege is occupied by a seven-run flouring-mill, which uses about half the power of the river at a low stage. It was stated as probable that a paper-mill would also be erected; if so, it could easily be supplied with straw from the surrounding section. The river here rises about 4 feet above low water, usually in June, and runs lowest in mid-summer or in a cold winter. Below the dam are rapids, with a fall of 4 or 5 feet in 2,000 feet. There is no unoccupied power between Charles City and Floyd, but a privilege could probably be developed below the former point. Passing up stream into Minnesota, there are found to be five flouring-mills in Mower county of that state, with heads ranging from 7 to 13 feet; the highest mill is probably one at Ramsey.

All along its course the Cedar receives, at intervals, little streams, such as Rock, Indian, Spring, Wolf, Black Hawk, Beaver, and Big creeks, and Little Cedar river, which sustain from one to four flouring- and grist-mills each. (*a*) The only important tributary, however, is Shell Rock river, which has already been alluded to.

SHELL ROCK RIVER.

This stream has its main source in Albert Lea lake, some 8 or 10 miles above the Minnesota boundary. It runs southeasterly for about 80 miles by general course, and 6 miles northwest of Cedar Falls, Iowa, unites with the main river. It drains an area of 2,631 square miles, having a slightly undulating surface and a comparatively thin covering of Drift.

Elevations and slope of the Shell Rock river.*

Locality.	Elevation above sea.	Fall between points.	Distance between points.†	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Rockford Station ‡	1,023	117	35	3.34
Shell Rock village ‡	906			
Cedar Falls (main river) §	845	61	15	4.07

* Taken from *Geology of Iowa*, with altitudes of datum planes corrected.
† Map measurement.
‡ By railroad survey.
§ River surface by Cedar Falls and Minnesota railroad levels.

As indicated by the rate of its descent, the Shell Rock is quite a rapid stream. There are numerous mills along its course, but many unutilized sites still remain. These are not all, however, equally suited to improvement. Thus, at Clarksville and vicinity the banks are low and considerable difficulty is experienced on that account. Ten miles up stream the bed is sandy, and the dam at Greene is constructed on piles; while at Rock Falls, in Cerro Gordo county, the site is excellent. The mills on the stream are located as follows, in succession from the mouth: Finchford, Shell Rock (two mills), Clarksville (two mills), Greene, Marble Rock, Rockford, one between Rockford and Nora Springs, Nora Springs, Rock Falls, Plymouth, one 3 or 4 miles above Plymouth, Northwood, and finally one at the outlet of Albert Lea lake. Most of these mills carry from two to four runs of stone each, and some are also provided with rollers; they have an average head of about 8½ feet.

The Shell Rock receives, in turn, two principal tributaries—West Fork and Lime creek; the former drains 858 square miles, and the latter 641 square miles. Lime creek rises in northern Winnebago county, close to the Minnesota line. It runs southerly and then southeasterly, and joins the Shell Rock at Rockford, in Floyd county. Above Fertile it is rather sluggish, but thence to the mouth, and especially below Mason City, it is very rapid in places. There is a flouring-mill at Rockford, one 4 miles below Mason City, and there are three or four above the latter point. There are also said to be many good sites for power still unimproved.

At Mason City Lime creek receives, through Willow creek, the drainage of Clear lake, which is located in the western part of Cerro Gordo county. This lake is described by Dr. White as being about 5 miles long, 2 or 3 miles broad, and having a maximum depth of 15 feet. Its shores are gravelly, and its banks mostly wooded. There is a two-run mill on the outlet. The lake yields ordinarily a very steady supply of water, but it is said to have fallen so low on one occasion that the privilege on the outlet was valueless for a year.

a Drainage area of Wolf creek, 321 square miles; Black Hawk creek, 366 square miles; Beaver creek, 410 square miles; Little Cedar river, 311 square miles.

Estimated volume and horse-power of the Cedar river and tributaries.

Stream and locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Cedar, at Charles City	989	70	80	90	102	130	148
Cedar, at Waverly	1,538	150	170	190	216	270	307
Cedar, at Cedar Falls	4,726	460	523	580	659	850	966
Cedar, at Waterloo	5,177	510	579	630	716	930	1,056
Cedar, at Cedar Rapids	6,543	640	727	800	909	1,180	1,340
Cedar, at Cedar Bluff	7,028	690	784	860	977	1,260	1,431
Cedar, above junction with Iowa river	7,715	740	841	920	1,045	1,350	1,534
Shell Rock, at Rockford, above Lime creek	621	60	68	80	91	110	125
Lime creek	641	60	68	80	91	110	125
West Fork	858	80	91	100	114	150	170
Shell Rock, at mouth	2,631	250	284	320	364	470	534

THE SKUNK RIVER.

This stream rises in Hamilton county, in the central part of Iowa, whence it runs southeasterly and, after forming the boundary between Des Moines and Lee counties, empties into the Mississippi. It is 200 miles long, by general course, with a drainage area of 4,409 square miles; the width of this area is for the most part quite uniform, ranging from 20 to 30 miles. The country has a rolling surface, well suited to agriculture, and along the lower river is moderately well supplied with hard-wood timber. Railroad lines cross the river and its basin at many points, but usually at so large an angle as to afford but limited facilities to the immediate course of the stream. Along the latter there are but few important towns; the more prominent, in order from the mouth, are Mount Pleasant (3 miles from river), population about 4,400; Brighton, in Washington county, 800; Colfax, in Jasper county, 700; and Ames, in Story county, 1,200.

Elevations and slope of the Skunk river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Southeast part of Hamilton county†	1,056			
		149	21	7.10
Near Ames, Story county†	907			
		148	36	4.11
Vowell's, Jasper county‡	759			
		209	108	1.94
Rome, Henry county§	550			
		45	38	1.18
Mouth of river‖	505			

* Map measurement.
† Water surface at Chicago and Northwestern railway crossing.
‡ Water surface at Chicago, Rock Island and Pacific railway crossing.
§ Low-water surface at Chicago, Burlington and Quincy railroad crossing.
‖ Low water in Mississippi river, by levels of Major Farquhar, connecting with lake Superior.

NOTE.—Elevations at Vowell's and at Rome are from *Geology of Iowa*, with altitudes of datum planes corrected.

The upper course of Skunk river lies over the Middle and Lower Coal Measures, but below the junction of the North and South Forks it runs along the border between the exposures of those formations and the sub-Carboniferous. The principal outcroppings of rock occur in the lower valley, especially in Henry and Des Moines counties, and consequently it is on the lower half of the river that the best mill-sites are to be found. The valley of the stream is, generally speaking, broad and flat, with gently-sloping sides, and covered with a rich, deep clayey soil. Along the lower course the bottom-land averages about 2 miles in width, but occasionally disappears where the bluffs approach simultaneously from either side. In addition to the first, and lowest, bottom, which is immediately beside the stream, there are generally to be discerned one, and even two, higher bottoms, or terraces, farther back. In this section the river bed is rocky; the banks are mostly of loam, with some rock exposures, and average 10 feet or more in height above low water. The lowest stage commonly occurs in August and September. The river is subject to great and rapid rises, during which the bottoms, and especially the first bottom, are seriously overflowed. These freshets, however, are said to have considerably decreased in magnitude of late years.

In the southeastern part of Keokuk county the South Skunk, or main river, is joined by the North branch, which drains a little less than half the area that the former does at their point of junction. Thence to the Mississippi, and above on both forks, there are many flouring-mills; they are mainly found below the northern limit of Mahaska county, there being but two or three on both streams above. From the western boundary of Henry county to the mouth the fall appears to be nearly all taken up, but above Henry county a considerable amount still remains open to improvement. So far as I could learn, the mills on the lower river are located as follows, in order from the mouth: Augusta, Bridgeport, Lowell (two mills), Boyleston, Otter Mills, Oakland, Star Mills, Merrimac, and Washington; the positions of those farther up stream may be sufficiently judged from the summary by counties, appearing in a subsequent table. The mills mentioned are all flouring-mills, and carry about three runs of stone each. The dams are generally framed structures, and furnish heads ranging from 4½ to 8 feet. It is said that the mills can, on the average, run ten months in the year at full capacity, but are troubled one month by low water, and one month by backwater; the Oakland mill suffered from backwater seven weeks during the spring of 1881. The privilege occupied by this mill is improved by a framed dam 325 feet long, 9 feet high, filled with stone and planked over. The head on the wheels varies from 5½ to 8 feet, but averages about 7 feet. The mill carries four runs of stone, and the proprietor roughly estimates that, with 6½ feet head, his privilege would carry fifty runs of stone for eight months in the year. A small woolen-mill of two sets has been in operation here, but was not running at the time of my visit. The chief obstacles to the establishment of woolen manufacturing in this section are described as being a lack of capital, and difficulty in obtaining good workmen.

The Skunk river is 300 to 400 feet wide in the vicinity of Oakland. Although it is a tolerably good stream, and furnishes power to many mills, it has not that steadiness of flow which characterizes the Cedar and Iowa, to the north; it is, in fact, quite unreliable, and while there will sometimes be an abundance of water for two successive years, in the third year it is liable to run very low.

Besides the North Fork, the most important tributary, this river receives in western Henry county Big Cedar creek, having a drainage area of 520 square miles, but unused for power except by one small saw-mill; and in Jasper county, from the east, Indian creek, draining 336 square miles, and having two flouring- and grist-mills of small size.

Estimated volume and horse-power of the Skunk river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Cambridge	726	40	45	60	68	80	91
Vowell's	1,275	80	91	100	114	150	170
Farmersville	1,654	100	114	130	148	200	227
Below North Skunk	2,745	170	193	220	250	330	375
Rome, below Big Cedar creek	4,037	240	273	330	375	490	557
Mouth of river	4,409	270	307	360	409	530	602
North Skunk, at Union Mills	444	20	23	40	45	60	68
North Skunk, at mouth	862	50	57	70	80	110	125

THE DES MOINES RIVER AND TRIBUTARIES.

The largest, and, in some respects, the most important, stream in Iowa is the Des Moines. Its source is in southwestern Minnesota, near the boundary between Lyon and Murray counties; it runs thence, in a generally southeasterly direction, across the state of Iowa to the Mississippi. It has a length, by general course, of 370 miles, for the last 23 of which it forms the boundary between Iowa and Missouri. At Des Moines its general direction changes to the eastward by something less than 30°, but either way from that point is quite straight; thus, if a straight line be drawn from the locality where the stream enters Iowa to Des Moines, and another from Des Moines to its mouth, its course, though showing many minor bends, will be nowhere distant more than 8 miles from the adjacent air-line.

The basin of this river comprises an area of 14,578 square miles, about 70 per cent. of which lies above Des Moines; its width is greatest in the upper part, and decreases from 75 or 80 miles at Fort Dodge to 50 miles at Des Moines and 20 miles at Ottumwa. The surface is a fertile, rolling prairie, quite flat in some sections, as toward the upper waters of the Raccoon; there is very little timber, except toward the mouth of the river, and even there what formerly existed has been largely cut away. Above the latitude of Des Moines there are to be found, scattered over the surface, many ponds of insignificant size, and in the upper basin a few lakes of some importance; the larger of these are Storm lake, with an area of about 7 square miles; Palo Alto, 6 square miles; Okamanpadu,

8½ square miles, and Heron lake (Jackson county, Minnesota), 11 square miles. (*a*) Okamanpadu and Heron lakes have visible outlets, but Storm and Palo Alto lakes appear isolated, though they doubtless contribute by percolation to neighboring water-courses; they are all of Drift origin, and are characterized by gravelly beds and shores, clear and rather shallow waters.

Not only does the area drained by the Des Moines possess fine agricultural resources, but in the vicinity of Fort Dodge there is a deposit of gypsum, said to be one of the most important in the United States and the only one of economic value in Iowa or the surrounding states; while, from below Fort Dodge to the mouth of the river, and covering nearly all that portion of the basin, stretch the Iowa coal-fields. The coal is bituminous, of good quality, and has already been mined at many points, mainly where exposed on the sides of the creek and river valleys. (*b*)

The railroad facilities of the Des Moines basin are, generally speaking, good, since it is traversed by a considerable number of important lines; but so far as concerns the development of water power they are of the most value on that part of the river below Mahaska county, for thence to the mouth the stream is closely followed by the Keokuk and Des Moines railroad; above Eddyville this road is distant 5 to 10 miles from the river on the north. For some 25 miles north of Fort Dodge the Minneapolis and Saint Louis railway also follows the main course of the river. At numerous other points it is approached or crossed by railway lines, but they have usually an east-and-west direction, and so traverse the valley at a considerable angle from its general direction.

The lower valley is the most thickly settled portion of the section we are considering, but in recent years, with the building of new railroads, the upper basin has attracted a considerable immigration. The population of the entire basin increased in the ten years previous to 1880 from about 237,000 to 349,000. The larger towns, in order as we ascend the river, are: Keokuk (near the mouth, on the Mississippi), population about 12,100; Bonaparte, 700; Keosauqua, 900; Eldon, 700; Ottumwa, 9,000; Eddyville, 900; Oskaloosa (6 miles from the river), 4,600; Pella (3 miles from river), 2,400; Knoxville (5 miles from river), 2,600; Des Moines, 22,400; Moingona, 1,000; Boonesboro', 3,300; Fort Dodge, 3,600; Emmetsburg, 900.

Elevations and slope of the Des Moines river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Windom, Minnesota †	1,329			
		365	111	3.29
Fort Dodge, Iowa ‡	964			
		43	31	1.39
Southeast part of Webster county §	921			
		44	24	1.83
Moingona §	877			
		91	40	2.27
Des Moines ‖	786			
		150	111	1.35
Ottumwa ¶	636			
		160	94	1.70
Mouth of river **	476			

* Distances above Des Moines are by map measurement; those below are by an old survey of the river.
† Water surface at Chicago, Saint Paul, Minneapolis and Omaha railway crossing.
‡ Water surface at Illinois Central railroad crossing.
§ Water surface at Chicago and Northwestern railway crossing.
‖ Water surface at mouth Raccoon river, based upon old survey.
¶ Water surface below dam, based upon old survey.
** Low water in Mississippi river, by survey of Major Farquhar connecting with lake Superior.

Eleven miles north of Fort Dodge the West Fork, or main river, is joined by the East Fork. The country drained by them is gently rolling. Their valleys range from a few hundred yards to half mile in width, and are depressed 50 to 150 feet below the general level of the surrounding uplands, to which there is a gradual rise. Their beds are more or less gravelly, but the banks are muddy. At Fort Dodge the depth of the valley is about 170 feet below the uplands, and is seldom exceeded at points farther down the river. From Fort Dodge to Amsterdam, in Marion county, the Des Moines runs through and upon the Lower Coal Measures, but natural exposures of these seldom occur in the valley, because of the deep overlying Drift. The bottom-land is in this section an eighth to a half mile wide, while the valley sides are irregularly sloping, and sometimes abrupt. Concerning that part of the river below Amsterdam, I quote from the *Geology of Iowa*:

> From Amsterdam to Ottumwa the sub-Carboniferous limestone appears at intervals in the valley sides again, forming low cliffs occasionally; but the exposures are generally small and distant from each other. Near Ottumwa the sub-Carboniferous rocks pass beneath the river again, bringing down the Coal Measure strata into its bed, but they rise again from it in the extreme northwestern corner of Van Buren county, and sub-Carboniferous strata resume and keep their place along the valley from there to the mouth of the river.

a These areas are as measured by planimeter on land-office maps.

b According to the Iowa *Agricultural Report* for 1879 there was mined in the state, during that year, 62,500,000 bushels of coal, of a value of $5,000,000.

The Des Moines river is not now a navigable stream, but some thirty years ago an attempt was made by the state of Iowa to establish slack-water navigation between the mouth and Des Moines city. (*a*) The original design contemplated a system of twenty-eight dams, with accompanying locks; two additional locks were to be provided in canals, of which 29.46 miles were to be excavated in order to shorten the river's course. The entire elevation to be overcome was about 310 feet, and the length of navigation to be secured 183.85 miles. By an act, approved August 8, 1846, Congress granted, in aid of the enterprise, 321,800 acres of public lands lying along the river below Raccoon Forks; subsequently, another grant of 1,000,000 acres, situated above Raccoon Forks, was made. Work was begun upon the lower river, and carried on at intervals between the years 1851 and 1856. At length, however, the general government refused to recognize the grant of 1,000,000 acres above Raccoon Forks, and work was permanently suspended. The water-privileges which had been developed by the building of dams were sold.

When work ceased upon the improvements, locks and dams had been completed at Croton, Bonaparte, and Bentonsport, and the lock-walls and abutments for the dam had been constructed at Keosauqua. Although work had been undertaken at other points also, no permanent structures had been built. The three dams were of crib-work, but, with the exception of that at Bonaparte, have since been carried away. The abutments and lock-walls were built of heavy limestone masonry, and still remain in fine condition.

That portion of the river below Des Moines, and, in particular, that part between Ottumwa and Croton, presents great advantages for development of water-power on an important scale, on account of the large volume and the generally favorable character of the bed and banks. There are numerous rock exposures, and from Ottumwa to Croton the bed is a smooth, even surface of limestone, while the banks are in the same distance of good height, averaging 20 feet above low water. In the vicinity of Bonaparte the bottom-land is quite narrow, not more than half a mile wide on the average, and in places steep rocky bluffs rise abruptly from the river on each side. The width of the stream increases from less than 400 feet below the mouth of the Raccoon to 500 feet near Ottumwa, and 600 feet in the vicinity of Bonaparte. Above Ottumwa the river banks are rather low, and the bottom-land is 1 mile to 2 miles in width. Below Saint Francisville the stream is meandering, with low banks and sandy bed.

The portion of the river we are now considering has a good current and a quite steady flow. The highest freshets occur in June, a month of heavy rains, but high water is also caused in spring by melting snows. The river banks, in the lower portion of its course at least, are seldom overflowed. The ordinary June rise in this section is 8 to 10 feet. The greatest recorded floods in the history of the river were those of 1851 and 1858, during the former of which years the rise in the lower river was 25 feet. At times, during high water, the Des Moines transports large amounts of drift, though no damage results from it. The greatest sources of trouble to the dams are the heavy runs of ice; the dams at Keosauqua and Bentonsport, and a part of the dam at Croton, have been carried away by this means. In view of this fact, and the size of the river, it is evident that improvements must be substantial and expensive.

Following is a list of the dams, with their locations, height, and lift, which were formerly designed for the purposes of slack-water navigation between the mouth and Ottumwa. They were all so planned as to position and height as to rest either wholly or in part upon rock foundation, and to cause but little overflow by backwater. Although the sites mentioned might not now be chosen for water-power improvements, still the table exhibits the localities at which it is practicable to obtain certain falls, as shown by actual survey:

Dams formerly planned to secure slack-water navigation in the Des Moines river below Ottumwa.

Location.	Height of dam.	Lift of lock.	Locality where fall, assumed equal to lift of lock, would be available.
	Feet.	*Feet.*	
No. 1, Saint Francisville	.....	32.0	Available by canal on north side from dam to mouth of river, a distance of 12 miles; 10 feet to be secured at lock 6 miles from dam, and 22 feet at guard-lock at end of canal (at low water in Mississippi).
No. 2, 7.25 miles by river above Saint Francisville	14.0	10.9	Available at dam.
No. 3, Croton	14.0	10.3	Available at dam; 8 feet now in use.
No. 4, 1 mile above Farmington	15.0	11.5	Available at dam.
No. 5, Bonaparte	11.0	7.5	Available at dam; 8 feet now in use.
No. 6, Bentonsport	15.0	12.3	Available at dam; 7 feet has been in use.
No. 7, Keosauqua	15.0	11.8	Available at dam; 11 feet has been in use
No. 8, 8.4 miles above Keosauqua	14.0	11.0	Available at dam.
No. 9, 6.4 miles below Iowaville	15.5	12.5	Do.
No. 10, 1.1 miles above Iowaville	15.5	12.4	Do.
No. 11, 8.25 miles above Iowaville	10.5	7.5	Do.
No. 12, 8 miles below Ottumwa	10.0	6.9	Do.
No. 13, 4 miles below Ottumwa	10.5	7.5	Do.

The first improved power met in ascending the Des Moines is opposite Croton, Lee county, Iowa. With the exception of 100 feet at each end, the upper crib-work of the old state dam at this point still remains; the rest has

a The reports of the improvement company and a profile of the river were procured for me through the efforts of Dr. J. M. Shaffer, of Keokuk.

been rebuilt of brush, with rock ballast. It rests upon a solid limestone bed, is 700 feet long and about 50 feet wide at the base. The masonry abutments are stated to be in good condition on both sides of the river; on the Iowa side, the head and shore walls of the lock are yet standing, but one-half of the river wall has been washed away. Power was formerly used on that side by a four-run flouring-mill and a saw-mill, but they were carried away by ice in 1866. On the Missouri shore there is now a two-run flouring-mill, using a head of 8 feet. Mr. S. P. Gray, of Croton, owns the privilege on the Missouri side, and would like to sell a portion of it.

Estimate of power at Croton.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 8 feet head.
	Sq. miles.			
Low water, ordinarily dry year	14,385	1,110	126.1	1,009
Low water, average year		1,300	147.7	1,182
Available ten months in average year		1,950	221.5	1,772

The next power is at Bonaparte, where the river has a width of 500 to 600 feet, a depth of 2 to 3 feet in an ordinary stage, and a good current. The state formerly built a dam at this point, which yet stands with the exception of the apron. As first built it consisted of a timber crib-work, filled in with stone, with a width of 20 feet at the base; it was supplemented by two successive low cribs on the down-stream side, forming offsets of 10 feet each, and together constituting an apron for the protection of the river bed. The effect of heavy ice running over the dam was to tear up the planking of the apron, and so destroy that portion, leaving only the main crib-work, having a base of 20 feet. In 1873 a new dam was constructed immediately below this, at a cost of $8,000 to $10,000. It is 666 feet long between abutments, and is similar in construction to the old dam above it; it is 18 feet wide at the base, 10 feet high at the crest, and 6 to 7 feet high at the back. It rests upon a limestone bed, and on the south side abuts against a timber and stone crib, while on the north side the wall of the old lock serves as an abutment. At the back of the dam is driven a double row of sheet-piling, and the remaining space to the breast of the old dam is packed with gravel. The new structure has no apron, and in consequence the overflow of the water has already worn some 2 feet into the river bed. The dam which I have described has given good satisfaction, and has withstood heavy runs of ice without injury. The pond extends 4 miles up the river. The head on the wheels is 8 to 8½ feet, and no trouble is experienced from backwater.

The Bonaparte power is owned by Messrs. Meek & Brothers, who run in connection with it a woolen-mill, a flouring-mill, and a small saw-mill. The woolen-mill was started in 1854, subsequently burned, and rebuilt in 1863. It carries six sets of cards and some other machinery, and gives employment to 75 or 80 hands. Cassimeres, blankets, jeans, and yarns are manufactured, and sold mainly in Iowa. The flouring-mill has five runs of stone. About 160 horse-power is used at this privilege, and the proprietors consider the supply of water sufficient, in the lowest stage, for at least three or four times that amount.

The first power above Bonaparte is that at Bentonsport. The dam, which stood until recently, was a crib-work structure filled with stone; it was 600 feet long, 24 feet wide at the base, 12 feet high at the breast, and 5 feet high at the back. It was owned by non-resident parties, who took but little interest in keeping it in repair; the timbers were alternately wet and dry, rapidly decayed, and the dam was very leaky; finally, during the winter of 1880–'81, it was carried away by the run of ice. The pond set back probably 6 to 8 miles, and a head of 7 feet was obtained. Mills were located on both sides of the river as follows:

	Horse-power.
On south side:	
One woolen-mill, two sets, about	35
One flouring-mill, four runs, about	48
On north side:	
One woolen-mill, (*a*) two sets, about	35
One flouring-mill, four runs, about	48
One paper-mill, (*a*) about	24
One saw-mill, about	20
Total power used, about	210

There was a scarcity of water for these mills in the dry season, but this was due solely to the leaky condition of the dam. At the time of my visit, in June, 1881, no repairs had been attempted, but the citizens of Bentonsport had formed a joint stock company, and a plan had been prepared for a new dam, (*b*) to cost about $10,000. It was thought that the work of construction would soon be under way. The proposed dam is to be a framed structure, consisting of bents 7 feet apart, each bent having four vertical posts, 7½ to 8 feet apart from center to center, set

a Mill had ceased operations before the date of the dam giving way. *b* See page 103.

into the rockbed at the base and properly braced. The dam will have a width at the base of about 24 feet, the crest rising 13 feet above the foundation; the top will be heavily planked, and slope up stream to the back, which is to have a height of 4 to 4½ feet above foundation. The interior of the dam will be packed with loose stone, and faced at the breast with 9 or 10 inches of concrete filling, contained between planking. The river bed is of limestone, and very favorable to the security of a well-built dam. The masonry abutments, built long ago by the state, remain in good condition. I was informed that upon the completion of the new dam the two flouring-mills would resume operations. It was desired to attract new enterprises to this point, and, to such, inducements would be offered which would probably include free rent and taxes, and possibly other aid. Bentonsport is a small place of 300 inhabitants, on the Keokuk and Des Moines railroad. There is a ferry running across the river, but no bridge.

Estimate of power at Bentonsport.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 10 feet head.
	Sq. miles.			
Low water, ordinarily dry year	14,197	1,090	123.8	1,238
Low water, average year		1,280	145.4	1,454
Available ten months in average year		1,920	218.1	2,181

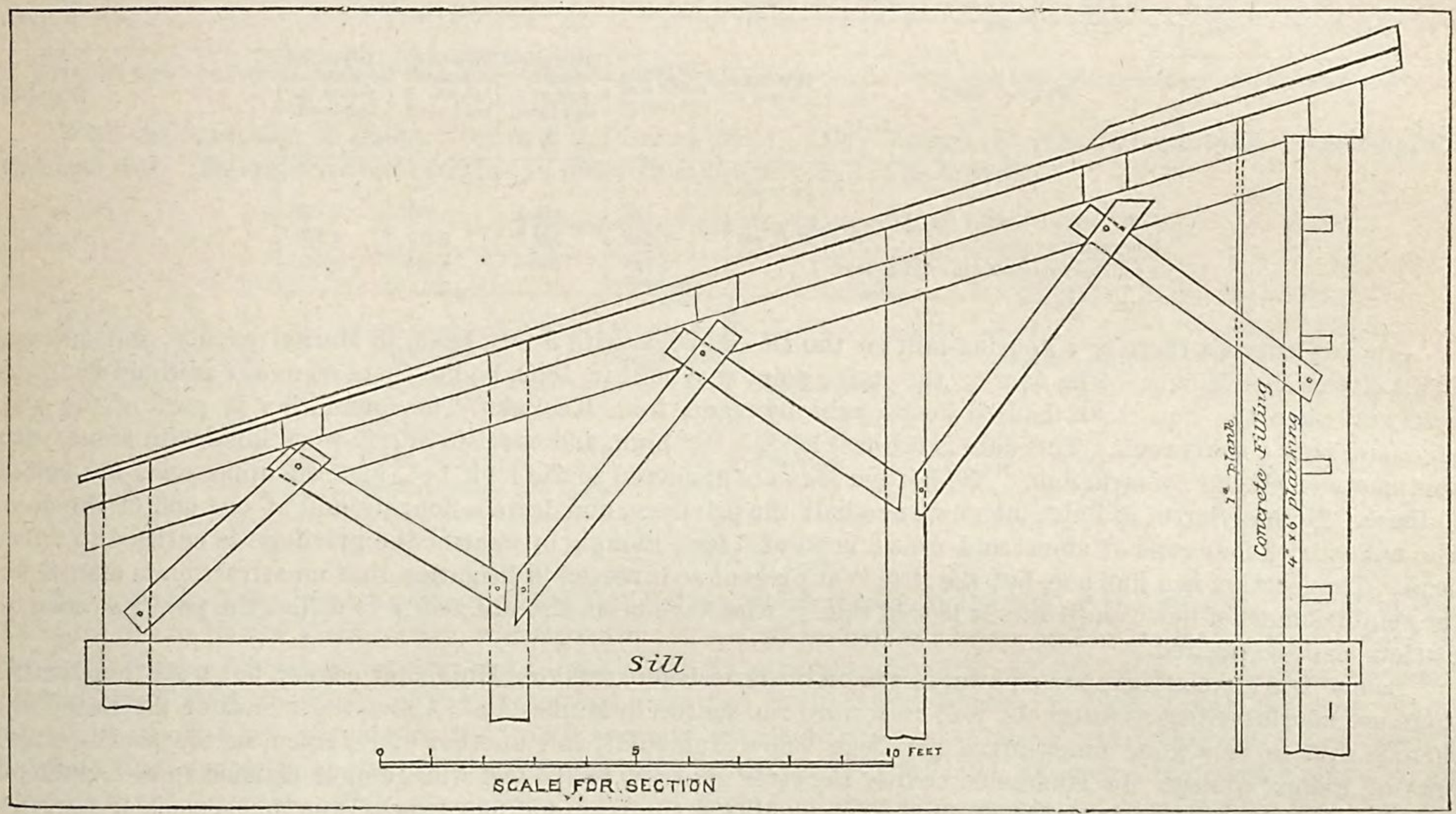
The Keosauqua power is the next in order. The town is very prettily situated on a bend in the river, and is connected with the Keokuk and Des Moines railroad by a short branch. In 1879 a crib-work dam was built across the river, but the workmanship was poor, the base was made altogether too narrow in proportion to the height, and in January, 1880, the structure was carried away in fifteen minutes after the ice started to run out. It had furnished a head of about 11 feet, and supplied power to a flouring- and grist-mill, of three runs, owned by Messrs. Wilson & Lee. These gentlemen, not being in a position to rebuild the dam in a substantial manner, have put steam-power into their mill. They would be very glad, however, to see the water privilege improved, and would offer strong inducements to secure that result. A new dam would need to be about 600 feet long. It would have for foundation a solid limestone bed, and for abutments the heavy masonry formerly built on each side of the river by the state, and which now stands in fine condition.

Estimate of power at Keosauqua.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 11 feet head.
	Sq. miles.			
Low water, ordinarily dry year	14,154	1,090	123.8	1,362
Low water, average year		1,280	145.4	1,599
Available ten months in average year		1,920	218.1	2,399

At Ottumwa somewhat of a manufacturing center has been established. A joint stock company was formed by the citizens of this place, and in 1875 the construction of two dams across the river, one on each side of Turkey island, was begun. The original contract price for dams, canal, and accompanying works was $64,000, plus an allowance per cubic yard of excavation. Disputes arose regarding the payment of the contractor, but a settlement was finally effected for about $64,000. The contractor is said to have left the dam, and, indeed, the whole work, in a very poor and incomplete condition. The west dam was a crib-work, filled in with sand and gravel, and was not properly protected by planking. The coffer-dam of brush, which had been built above the permanent structure, was left in place, and in January, 1877, not long after the work was turned over by the contractor, the water pouring over the brush coffer rapidly wore out the filling of the dam below, and about 40 feet of it was carried away. In the fall of 1877 the dam was repaired, and then stood for one year, when it had to be entirely rebuilt. In order to meet the various expenses arising, considerable sums of money have been advanced, on the security of the works, by eastern parties, and the total expenditure connected with the enterprise now amounts to about $120,000.

The west dam is now ballasted with stone, and has an apron of the same construction as its own. The east dam is also a crib-work. Both are of about the same height, and each is 350 feet long. They rest upon a firm rock bottom, and are protected at the ends by substantial abutments of masonry. From above the dams a large main race, 4,300 feet long, runs in a southeasterly direction, across the neck of a bend in the river, to the mills, and terminates in a bulkhead. Twelve hundred feet below the upper entrance to the race there is a guard-



DAM AT BENTONSPORT.

387

lock, or bulkhead, measuring 200 feet across the race, and built of masonry. The river brings down considerable sediment, which enters the race between the dam and guard-lock and forms a troublesome deposit. The full head attainable at the mills is 10 feet, but only 8 to 8½ feet is now available, and no more will be till a small amount of blasting shall be done in the tail-race. The following concerns are supplied with power, some of them also using steam: Ottumwa Cutlery Company, City Water Works, Ottumwa Starch Works, Johnson Ruffler Company, Ottumwa Iron Works, an oil-mill, and a flouring-mill. About 275 horse-power of water is used in all. (*a*) There is always an abundance of water, and the theoretical power of the river at this point, with 10 feet head, and in a medium stage, has been estimated at 3,000 horse-power. My own estimate of the power at lower stages is given below. For a short time in the year the mills are troubled by backwater. They are conveniently situated, and close at hand are the tracks of the Chicago, Burlington and Quincy, and Chicago, Rock Island and Pacific (Keokuk and Des Moines division) railroads. Mr. S. L. Wiley now holds the property pertaining to the water-power, as trustee. No regular rate is established for the use of water, and the affairs of the company were in such condition at the time of my visit that no inducements could be held out to manufacturers, nor were any efforts being made to attract them to this point.

Estimate of power at Ottumwa.

Stage of river.	Drainage area.	Volume, cubic feet per second.	Theoretical horse-power, 1 foot head.	Theoretical horse-power, 8 feet head.	Theoretical horse-power, 10 feet head.
	Sq. miles.				
Low water, ordinarily dry year	13,465	1,040	118.1	945	1,181
Low water, average year		1,210	137.5	1,100	1,375
Available ten months in average year		1,820	206.8	1,654	2,068

Above Ottumwa there is a flouring-mill on the Des Moines, with 5 feet head, in Marion county, and another at the city of Des Moines. The dam at the latter point was built in 1862, before there were any railroad facilities here, and when the iron for it had to be brought by teams from Keokuk. The foundation is part of the way sand, and part a shaly rock. This dam is 600 feet long, 5 feet high, and consists of crib-work filled with stone, with abutments of similar construction. The bottom logs are anchored to the rock bed, and the upper ones are bolted to these. Messrs. Serrin & Fairbanks own one-half the privilege, and have a flouring-mill at one end of the dam. The mill carries four runs of stone, and uses a head of 5 feet, though by charter the privilege is entitled to 9 feet head. The location is a fine one, but the title is at present so involved in litigation that no attraction is offered for the establishment of new concerns. It is said that parties have been, and are, ready to utilize the power so soon as matters shall be righted.

Above Des Moines there is no power in use on the river before reaching Humboldt county, but from that section there are flouring-mills, at intervals, well on toward the source in Minnesota. Above the mouth of the East Fork there is said to be a good unimproved privilege below Humboldt, and another at Petersen, in the southwestern part of Emmet county. In Humboldt county the river runs 100 to 125 feet wide, and is claimed to be capable of carrying six runs of stone, with 7½ feet head, nine months in the year, and four runs all the time, except in very dry seasons or unusually cold winters; in the latter case, very thick ice forms, and there is but little water running.

Below the mouth of the East Fork, and for a considerable distance below Fort Dodge, the river is 200 to 250 feet wide, with rather low banks. The bed is largely Kinderhook limestone, the strata of which dip to the southwest at a somewhat greater pitch than that of the river. The latter has a moderate fall, without important rapids, and numerous water privileges may be found, with an available head of 6 or 8 feet; dams of greater height would be likely to cause overflow of the banks. The river bed in this section contains many springs, which preserve open spots in the ice during winter, long after the rest of the stream is frozen over, and are resorted to by wild fowl. Corn and stock are the principal exports of the country about Fort Dodge. It does not appear to be so well adapted to winter wheat as that farther south, or to spring wheat as that to the north, in Minnesota. Flax is a successful crop, and its production is increasing. Bituminous coal, brick-clay, and building-stone of fair quality, are obtained at Fort Dodge, in addition to gypsum from the valuable deposits.

a Seventy horse-power of steam is also employed.

Estimated volume and horse-power of the Des Moines river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Below Heron lake outlet	979	50	57	60	68	80	91
Emmetsburg	1,766	90	102	110	125	170	193
Below East Fork	3,951	250	284	300	341	440	500
Fort Dodge	4,537	290	329	340	386	510	579
Boonesboro'	5,919	400	454	460	523	700	795
Above Raccoon river	6,672	470	534	550	625	830	943
Below Raccoon river	10,000	740	841	860	977	1,300	1,477
Below Middle Three river	11,120	840	954	970	1,102	1,460	1,659
Bennington	11,822	900	1,022	1,050	1,193	1,580	1,795
Ottumwa	13,465	1,040	1,181	1,210	1,375	1,820	2,068
Keosauqua	14,154	1,090	1,238	1,280	1,454	1,920	2,181
Mouth of river	14,578	1,130	1,284	1,310	1,488	1,970	2,238

NOTE.—It should be borne in mind that the volumes as here estimated are the average for the twenty-four hours, and are independent, therefore, of storage in mill-ponds.

With the exception of Boone river and the East Fork, the Des Moines receives no important accessions from the east side. The principal tributaries, in order from the mouth, are as follows:

Tributaries of the Des Moines river.

Stream.	Drainage area.	Stream.	Drainage area.
	Square miles.		*Square miles.*
Cedar creek	425	Raccoon river	3,329
White Breast river	419	Beaver creek	410
South river	606	Boone river	899
Middle Three river	592	East Fork	1,357
North river	374		

RACCOON RIVER.

This stream is the largest affluent of the Des Moines, which it joins at the city of Des Moines. The main fork takes its rise in Buena Vista county, whence it runs in a southeasterly direction, and in Dallas county is joined by the South Fork. The Raccoon river has a total length by general course of about 125 miles. The country drained by the North Fork is gently rolling, becoming quite flat in the upper basin. In that section the river drains numerous small lakes, varying from 1 to 40 acres in extent, and some of larger size. Once in a few years it happens that, owing to continued heavy rains, these lakes get very full and prolong a high-water stage in the river for several months. This branch flows through bottom-land ranging from a mile to a mile and a half in width. The bed is in part sand, and in part a hard blue clay, which affords a fine foundation for dams. About 50 per cent. of the banks are estimated to be bluffy; elsewhere they average 10 to 12 feet in height. The stream is rather crooked, and at Adel is said to make a long bend of 7 miles, the distance across the neck of which is only 1 mile. In a medium stage the North Fork is 100 to 125 feet wide, and 6 to 10 feet deep in the eddies; shoals occur once in half a mile or a mile, where the depth is perhaps 2 feet. The flow is quite steady, though occasionally in winter the stream runs very low. The current is somewhat sluggish compared with that of the South Fork, and the mills on its course are troubled by backwater about one month in the year. The stream has a gradual rise and fall, but both the North and South Forks overflow their banks on the average once in every alternate year.

The South Fork—and the characteristics of the Middle Fork are about the same—flows through a rougher country than the stream I have just described, and its banks are more bluffy than those of the latter. The bottom-lands are of about the same width on both branches, and the streams themselves are approximately equal in size. The South Fork, however, is straighter, less deep, has a more rapid current, and shoals more frequently. There is but little trouble on this stream from backwater. It has a rocky bed, is subject to sudden rise and fall after heavy rains, but, being largely fed by springs, has a well-sustained volume in the dry season.

The country drained by the Raccoon and its branches is not, as yet, thickly settled, but it is intersected by several railway lines and is increasing in population. I was informed by a gentleman familiar by long experience with both streams, that neither the North nor the South Fork is yet improved to more than 50 per cent. of its capacity, although they are employed for power by a considerable number of flouring-mills. The dams are reported to have stood well; they are commonly of crib-work, filled with brush and stone. The mill at Adel, on the North Raccoon, is situated on a slough, into which water is diverted from the river by a low rude dam; it has a head of 12 feet, and carries four runs of stone.

Elevations on the North and Middle Raccoon rivers.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
NORTH RACCOON.	*Feet.*	*Feet.*	*Miles.*	*Ft. per mile.*
West of Newell †	1,246	246	67	3.67
West of Jefferson ‡	1,000	214	66	3.24
Des Moines §	786			
MIDDLE RACCOON.				
Carroll Station ‖	1,276	490	93	5.27
Des Moines ¶	786			

* Map measurement.
† Water surface at Illinois Central railroad crossing. (From *Geology of Iowa.*)
‡ Water surface at Chicago and Northwestern railway crossing.
§ Water surface at mouth, by old survey.
‖ Chicago and Northwestern railway levels.
¶ Water surface, as above.

BOONE RIVER.

This river heads in Kossuth and Hancock counties, and flows southerly, joining the Des Moines from the east, 19 miles southeast of Fort Dodge; it is about 60 miles long by general course. Through Wright county its bed is composed of Drift material, but at Webster City it reaches the underlying rock, which is thereafter frequently exposed. The stream is comparatively small, but furnishes power to four flouring-mills, carrying two to four runs of stone each.

EAST FORK OF THE DES MOINES RIVER.

This stream has its extreme source in Jackson county, Minnesota, some 9 miles north of the Iowa boundary; its principal source, however, may be said to be in lake Okamanpadu, immediately south of that boundary. It flows southeasterly, and then southerly, joining the main river 11 miles north of Fort Dodge. Down to within a few miles of its mouth it is said to be, in general, a sluggish stream, with soft bed and banks, the latter quite low. At Algona it is 100 to 125 feet wide, and flows through a valley half a mile or a mile in width; its course is in the Drift formation, into which it does not cut its way sufficiently to expose the underlying limestone until it reaches the vicinity of Dakota. On either side of the valley rise low bluffs, beyond which is the open prairie. The latter is covered with soil of fair quality, not so rich as farther south, and is so slightly undulating as to appear level; it abounds in shallow basins, which are filled with water and choked with grass and weeds, and which usually have no visible outlet.

It is stated that lake Okamanpadu might be raised 4 feet by building a dam at its outlet. A mill privilege would thus be created a short distance below, with a head of 8 feet, and the flow of the stream would also be made more uniform. From the outlet of the lake down to Dakota the fall is reported to be so moderate, and the banks are said to be so low, that there are few opportunities for the further use of power. At Algona there is a four-run flouring-mill, using a head of 7½ feet; the dam consists of piles backed with loose stone, and rests upon a foundation of gravel, clay, and quicksand. At Dakota there is a three-run flouring-mill, with 7½ feet head. During freshets the river spreads out over the bottom-land, and the mills are hindered by backwater. As the ice moves down the river it is usually deposited on the flats, and causes no injury to the dams in this section; but farther down stream, where the banks are higher, it sometimes gives trouble.

Estimated volume and horse-power of tributaries of the Des Moines river.

Stream and locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
North Raccoon:	*Sq. miles.*						
At Grant City	724	40	45	60	68	100	114
At Northville	1,294	80	91	110	125	170	193
Above South Fork	2,001	150	170	190	216	280	318
Middle Raccoon above South Fork	592	30	34	60	68	80	91
South Raccoon:							
Above Middle Fork	389	20	23	40	45	50	57
Below junction	981	60	68	100	114	130	148
Above North Fork	1,144	80	91	110	125	160	182
Main Raccoon:							
Below junction North and South Forks	3,145	250	284	300	341	440	500
At mouth	3,329	270	307	310	352	470	534
Boone river:							
At Bach Grove	517	20	23	40	45	60	68
At mouth	899	50	57	70	80	100	114
East Fork Des Moines:							
At Algona	980	50	57	80	91	120	136
At mouth	1,357	70	80	110	125	170	193

Power utilized on the rivers of eastern Iowa.

[Below Dubuque, to and including Des Moines river.]

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Maquoketa	Mississippi	Iowa	Jackson	Flour and grist	1	12	48
Do	do	do	do	Flour, grist, and saw	2	14	90
Do	do	do	do	Saw	1	6	30
Do	do	do	Jones	Flour and grist	2	14	100
Do	do	do	Delaware	Flour, grist, and saw	1	11	65
Do	do	do	do	Flour and grist	5	56	255
Do	do	do	Buchanan	do	1	16	5
Do	do	do	Clayton	do	1	8	20
North Maquoketa	Maquoketa	do	Jackson	do	1	8	56
Do	do	do	do	Woolen	1	7	100
Do	do	do	Dubuque	Flour and grist	3	31	82
Do	do	do	do	Flour, grist, and saw	1	11	100
Do	do	do	do	Woolen	1	11	6
Small streams	do	do	Jackson	Flour and grist	5	54	192
Do	do	do	Jones	Flour, grist, and saw	1	12	40
Do	do	do	Delaware	Flour and grist	3	32½	49
Do	do	do	do	Saw	1	14	14
Do	do	do	do	Woolen	1	10	38
Do	North Maquoketa	do	Jackson	Flour and grist	3	31½	139
Do	do	do	do	Saw	1	7	25
Wapsipinicon	Mississippi	do	Clinton	Flour and grist	2	11	100
Do	do	do	Jones	do	3	19½	175
Do	do	do	Linn	do	2	14	88
Do	do	do	Buchanan	do	3	29	278
Do	do	do	Black Hawk	do	1	6	16
Do	do	do	Bremer	do	1	6	60
Do	do	do	Mitchell	do	1	9	27
Small streams	Wapsipinicon	do	Clinton	do	5	47	120
Do	do	do	Jones	do	1	7	55
Do	do	do	Linn	do	2	15½	53
Do	do	do	Buchanan	do	3	28	80
Do	do	do	Fayette	do	2	18	40
Iowa	Mississippi	do	Louisa	Flour, grist, and saw	1	9	85
Do	do	do	Johnson	Flour and grist	1	4	50
Do	do	do	Johnson (Coralville)	(See description)	3	9–11	696
Do	do	do	Iowa (Homestead)	do	6	8–12	335
Do	do	do	Iowa	Flour and grist	1	6	100
Do	do	do	Tama (Tama City.)	do	1	21	40
Do	do	do	do (Tama City.)	Wind-mills	1		10
Do	do	do	do (Tama City.)	Cooperage	1		8
Do	do	do	do (Tama City.)	Agricultural implements	1		20
Do	do	do	do (Tama City.)	Sash and blinds	1		10
Do	do	do	do (Tama City.)	Paper	1		40
Do	do	do	Tama	Flour and grist	2	13½	110
Do	do	do	Marshall	do	3	18	176
Do	do	do	Hardin	do	9	72	545
Do	do	do	do	Woolen	1	10	50
Do	do	do	Wright	Flour and grist	1	7	12
Do	do	do	Hancock	do	1	9	20
English	Iowa	do	Washington	do	3	24	142
Do	do	do	Iowa	do	3	22	77
Deer creek	English	do	Johnson	Saw	1	5	14
Small streams	Iowa	do	do	Flour and grist	2	12	38
Do	do	do	Iowa	do	2	16	59
Do	do	do	Tama	do	4	35½	97
Cedar	do	do	Muscatine	do	1	4½	80
Do	do	do	Linn (Cedar Rapids)	do	4	6–8	315
Do	do	do	do	Foundery and machine	1		20
Do	do	do	do	Sash and blinds	1		80
Do	do	do	Linn	Flour and grist	2	21	30
Do	do	do	Black Hawk (Waterloo)	(See description)	5	5	402
Do	do	do	Black Hawk (Cedar Falls.)	do	9	8–9	491
Do	do	do	Black Hawk	Flour and grist	2	13	26
Do	do	do	Bremer	do	3	21	205
Do	do	do	do	Woolen	1	7	27
Do	do	do	Chickasaw	Saw	1	5	18
Do	do	do	do	Flour and grist	2	16½	110
						391	

Power utilized on the rivers of eastern Iowa—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Cedar	Iowa	Iowa	Floyd	Flour and grist	2	18	210
Do	do	do	Mitchell	do	7	51	458
Do	do	do	do	Flour, grist, and saw	1	7½	118
Do	do	do	do	Woolen	1	13	27
Do	do	Minnesota	Mower	Flour and grist	5	47½	269
Small streams	Cedar	Iowa	Cedar	do	6	102½	149
Do	do	do	Linn	do	7	94	163
Do	do	do	do	Woolen	1	17	5
Do	do	do	Benton	Flour and grist	2	35	55
Do	do	do	Tama	do	2	17	85
Do	do	do	Buchanan	Cheese and butter	1	3	6
Do	do	do	Black Hawk	Flour and grist	2	16	55
Do	do	do	do	Cheese and butter	1	4	1
Do	do	do	Franklin	Flour and grist	1	36	55
Do	do	do	Chickasaw	do	1	10	38
Do	do	do	Mitchell	do	2	16½	56
Do	do	Minnesota	Freeborn	do	1	9	40
Do	do	do	Mower	do	1	16	30
Shell Rock	do	Iowa	Butler	do	5	33	259
Do	do	do	Floyd	do	4	35	282
Do	do	do	Cerro Gordo	do	2	28	115
Do	do	do	Worth	do	2	16	130
Do	do	do	do	Woolen	1	8	10
Do	do	Minnesota	Freeborn	Flour and grist	1	5½	15
Small streams	Shell Rock	Iowa	Black Hawk	do	1	6½	40
Do	do	do	Butler	do	3	26	88
Do	do	Minnesota	Freeborn	do	1	18	40
Lime	do	Iowa	Floyd	do	1	10	75
Do	do	do	Cerro Gordo	do	5	43	222
Willow	Lime	do	do	do	1	11	50
Skunk	Mississippi	do	Lee	do	1	6½	25
Do	do	do	Des Moines	do	1	7	45
Do	do	do	Henry	do	5	31	282
Do	do	do	Jefferson	do	1	7	70
Do	do	do	Washington	do	1	6	50
Do	do	do	do	Flour, grist, and saw	1	9	55
Do	do	do	Keokuk	do	1	8	50
Do	do	do	do	Flour and grist	2	22	135
Do	do	do	Mahaska	do	4	24	113
Do	do	do	Story	do	1	8	100
Small streams	Skunk	do	Henry	Saw	1	7	15
Do	do	do	Jefferson	Flour and grist	1	9	18
Do	do	do	Jasper	do	2	16	42
North Skunk	do	do	Keokuk	do	1	10	26
Do	do	do	Mahaska	do	6	48½	249
Do	do	do	Poweshiek	do	2	17	70
Des Moines	Mississippi	Missouri	Clarke	do	1	8	20
Do	do	Iowa	Van Buren (Bonaparte)	(See description)	3	8	160
Do	do	do	Van Buren (Bentonsport)	do	4	7	151
Do	do	do	Wapello (Ottumwa)	do	7	8½	275
Do	do	do	Marion	Flour and grist	1	5	75
Do	do	do	Polk	do	1	5	120
Do	do	do	Humboldt	do	3	38	217
Do	do	do	Palo Alto	do	1	8	80
Do	do	Minnesota	Jackson	do	3	25½	208
Do	do	do	Cottonwood	do	1	10	70
Do	do	do	Murray	do	1	8	51
Middle river	Des Moines	Iowa	Warren	do	1	7½	50
Do	do	do	do	Flour, grist, and saw	1	6	38
Do	do	do	Madison	Flour and grist	3	34	78
Do	do	do	Adair	do	3	35½	41
Raccoon	do	do	Polk	do	2	9	60
Do	do	do	Dallas	do	2	11½	75
North Raccoon	Raccoon	do	do	do	2	19	100
Do	do	do	Greene	do	5	38	108
Do	do	do	Carroll	do	1	7	20
Do	do	do	Calhoun	do	1	10	18
Do	do	do	Sac	do	2	19	62

Power utilized on the rivers of eastern Iowa—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Middle Raccoon	South Raccoon	Iowa	Dallas	Flour and grist	1	11	30
Do	do	do	do	Flour, grist, and saw	1	7	40
Do	do	do	Guthrie	Flour and grist	3	27	102
Do	do	do	do	Saw	1	6	25
South Raccoon	Raccoon	do	Dallas	Flour and grist	3	20½	112
Do	do	do	do	Flour, grist, and saw	1	6	106
Do	do	do	Guthrie	Woolen	1	6½	24
Do	do	do	do	Flour and grist	4	39	149
Boone	Des Moines	do	Hamilton	do	6	43½	179
East Fork Des Moines	do	do	Humboldt	do	1	7½	(?) 45
Do	do	do	Kossuth	do	1	7½	57
Small streams	Mississippi	do	Dubuque (below Dubuque city).	do	3	60	71
Do	do	do	Jackson	do	8	117	324
Do	do	do	Clinton	do	7	112	164
Do	do	do	do	Flour, grist, and saw	1	12	60
Do	do	do	Muscatine	Flour and grist	1	20	70
Mississippi		do	Scott	do	2		*110
FIRST SUMMARY.							
Maquoketa	Mississippi	do			14	137	613
North Maquoketa	Maquoketa	do			7	68	344
Small streams	Maquoketa and North Maquoketa.	do			15	161	497
Wapsipinicon	Mississippi	do			13	94½	744
Small streams	Wapsipinicon	do			13	115½	348
Iowa	Mississippi	Iowa			35	192½	2,307
Cedar	Iowa	Iowa and Minnesota.			48	247	2,886
Shell Rock	Cedar	do			15	125½	811
Small streams	Iowa	Iowa			15	114½	427
Do	Cedar and tributaries	Iowa and Minnesota.			40	490½	1,253
Skunk	Mississippi	Iowa			18	128½	925
North Skunk	Skunk	do			9	75½	345
Small streams	do	do			4	32	75
Des Moines	Mississippi	Iowa and Minnesota.			26	131	1,427
Middle	Des Moines	Iowa			8	83	207
Raccoon	do	do			4	20½	135
North Raccoon	Raccoon	do			11	93	398
Middle Raccoon	South Raccoon	do			6	51	197
South Raccoon	Raccoon	do			9	72	391
Boone	Des Moines	do			6	43½	179
East Fork Des Moines	do	do			2	15	102
SECOND SUMMARY.							
Maquoketa and all tributaries.	Mississippi	do			36	366	1,454
Wapsipinicon and all tributaries.	do	do			26	210	1,092
Iowa and all tributaries	do	Iowa and Minnesota.			153	1,170	7,684
Skunk and all tributaries	do	Iowa			31	236	1,345
Des Moines and all tributaries.	do	Iowa and Minnesota.			72	509	3,036
Sundry small streams	do	Iowa			20	321	689
Mississippi		do			2		110
Total eastern slope of Iowa, below Dubuque.					340	2,812	15,416

* Current-wheels.

VII.—THE EASTERN MISSOURI SLOPE.

For convenience I include in this division those rivers, other than the Missouri, which flow into the Mississippi from the west, below the Des Moines, down to, and including, the Saint Francis; the latter has much of its course within Arkansas, but the upper waters, the only portion having any available power, lie in Missouri. Between Des Moines and the Missouri rivers are encountered, successively, the following streams: Fox river, drainage area, 450 square miles; Wyaconda river, 452 square miles; Fabius river, 1,523 square miles; North river, 468 square miles; Salt river, 2,956 square miles; and Cuivre river, 1,088 square miles. It may be said, in brief, regarding these streams, that they have practically no value for power. They are very sluggish, and are thought to have a fall in the main portions of their courses but slightly greater than that of the Mississippi, which sets up into them for 2 or 3 miles above their mouths. They drain a rather rough country, well wooded, but entirely deficient in springs; being forced, therefore, to depend upon surface drainage, they are characterized by great unevenness of flow; during summer they run very low, and some, such as the Fabius, are said to become dry; on the other hand, after heavy rains they rise quickly, overflow their banks, and submerge their valleys far and wide. Salt river is the largest of these streams, but probably would not itself furnish power, in low water, for more than a moderate-sized grist-mill. It runs through a valley half a mile to a mile wide, its own width between banks being about 300 feet. These are 12 to 15 feet high above low water, but during freshets the river rises 4 to 8 feet above them.

THE MERAMEC RIVER.

This is the first important stream south of the Missouri. It rises in Phelps and Dent counties, pursuing thence a northeasterly course to the Mississippi, which it reaches about 20 miles to the south of Saint Louis. It drains an area of 3,914 square miles, the surface of which is rough and broken, thickly timbered, and with a rather shallow covering of soil. The river runs through a valley ranging from a quarter of a mile in width, in the upper course, to three-quarters of a mile toward the mouth. Limestone cliffs frequently rise abruptly from the water, while on the opposite side of the stream is a level bottom subject to overflow in high water. The bed is usually of gravel, though rock ledges and bowlders occasionally appear. The upper river is described as a chain of rapids, and these continue, at longer intervals, down stream; none of them, however, are of great pitch, the largest fall at any point below Phelps county being 6 feet in 950 yards, 15 miles from the Meramec iron-works. The banks vary considerably in height, but, exclusive of the bluffs, average 10 to 12 feet above low water; where succeeded by bottom-land, they are composed of alluvial soil underlaid by gravel.

Elevations and slope of the Meramec river.

Locality.	Elevation above sea.	Fall between points.*	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile*
Head spring	755½			
		140	38¼	3.66
Mouth of Courtois	615½			
		157	49¾	3.16
Mouth of Bourbeuse	458½			
		51½	28	1.84
Mouth of Big river	407			
		42	56½	0.74
Mouth of Meramec†	365			

* From report by William H. Morell, chief engineer, to the Missouri legislature, in 1840.
† Low water in Mississippi river, by levels of precision under Mississippi River Commission.

The Meramec is not a navigable stream. It was examined in 1880, under the direction of Captain O. H. Ernst, corps of engineers, but the expense of rendering it navigable was found so large, in comparison with the commerce of the valley, as to forbid such improvement. The Saint Louis and San Francisco railroad follows the greater part of the course of the river, nowhere distant more than 7 or 8 miles from it (except toward the mouth), and the Missouri Pacific road also runs along the lower valley for some distance.

The width of the river increases from about 150 feet in its upper course to 200 feet in the middle course, and 300 or 400 feet near the mouth. The steep rocky slopes of the country drained quickly shed into the stream the water of heavy rains, and sudden, rapid rises occur. The range between high and low water is 8 to 12 feet in the upper waters, and 17 to 20 feet in the middle and lower portions. The principal rise is in the spring.

The use of the Meramec for power is confined to a few small flouring- and grist-mills of one or two runs each. Only one of these was visited by me—that located in Phelps county near a remarkable spring which is the source of one of the upper forks. This spring is at the foot of a hill, and discharges into a pool of half an acre to an acre in

extent, formed by a rude dam of stones. A race some 400 feet long starts from the pool, and conveys water to a small flouring-mill using 12 feet head and 20 horse-power. The flow from this spring is estimated at 100 to 150 cubic feet per second, and is very uniform, though greater in spring than in summer. The stream issuing from it I observed to be 50 to 75 feet wide, 3 or 4 feet deep, and running with rapid current. At the distance of half a mile it unites with the East Fork. The Meramec iron-works, immediately below the spring, formerly used its waters for power to run a blast-furnace and forge, employing a head of 12 feet and several water-wheels, rated in the aggregate at 300 horse-power. These works were quite extensive, but are not now in operation.

The Meramec has sufficient volume to supply powers of considerable size, the chief disadvantages to its use being the sudden and rather heavy freshet rises, and the difficulty of finding high firm banks simultaneously on both sides. The discharge of the stream at its mouth, as estimated by Mr. Max E. Schmidt, who conducted the government reconnaissance in 1880, is about 600 cubic feet per second in extremely low water, or 0.15 cubic foot per second per square mile of drainage area. The average rainfall on the basin is 11½ inches in spring, 12 in summer, 8 in autumn, 7 in winter, and 38½ for the year. I estimate the volume and horse-power at different points on the river as follows:

Estimated volume and horse-power of the Meramec river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Below Courtois	1,325	210	239	290	329	390	443
Southern edge Franklin county	1,529	230	261	330	375	440	500
Below Bourbeuse	2,680	400	454	500	568	690	784
Mouth of river	3,914	580	659	700	795	970	1,102

Below the junction of what are known as the Dry Fork and Water Fork, the principal tributaries of the Meramec are the Courtois, drainage area 450 square miles; Bourbeuse, 831 square miles, and Big river, 919 square miles. The Bourbeuse and Big rivers discharge 70 to 100 cubic feet per second in a low stage, and the latter with its tributaries furnish power to quite a number of flouring- and grist-mills, all, however, of small size and averaging not over 20 horse-power each.

Table of power utilized on the Meramec river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Meramec	Mississippi	Missouri	Franklin	Flour and grist	1	17½	10
Do	do	do	Crawford	do	2	23	23
Do	do	do	Dent	do	1	12	16
Big	Meramec	do	Jefferson	do	3	19	74
Do	do	do	Saint François	do	2	13	35
Small streams	Big	do	do	do	1	24	12
Do	do	do	Washington	do	11	190	210
Do	Meramec	do	Franklin	do	2	13	32
Do	do	do	Washington	Saw	1	33	15
Do	do	do	Crawford	Flour and grist	6	79	70
Do	do	do	Phelps	do	1	12	20
Total					31	435½	517

THE SAINT FRANCIS RIVER.

This river, the only important one joining the Mississippi from the west between the Meramec and the Arkansas, has its sources in Saint François and Iron counties, in southeastern Missouri; it runs southerly into Arkansas, its course throughout being approximately parallel to that of the Mississippi, and empties a short distance above Helena. Its water-shed lines are not easily traced, but embrace an area of at least 8,000 square miles. This section presents two marked varieties of surface. The upper waters of the river drain an elevated region constituting a slope of the Ozark mountains, which strike easterly through southern Missouri. This slope falls away quite rapidly toward the south and east, and is the only portion of the Saint Francis basin possessing water-power of any value; it has

valuable resources, and abounds in iron, copper, and lead; deposits of zinc and other minerals are also found. At the headwaters are Pilot Knob and Iron mountain, almost solid masses of iron ore of the greatest purity. Granite and porphyry hills rise in some cases 600 or 700 feet above the river, and in various localities there are quarries of granite, sandstone, and limestone, suitable for building purposes. This upper basin is well timbered with a young growth, comprising oak, ash, hickory, walnut, poplar, beech, and pine; the soil is fertile, and yields good crops of corn, wheat, oats, and rye.

South of this elevated portion of its basin the Saint Francis enters upon a low, partially sunken region, extending from the southern boundaries of Wayne, Bollinger, and Cape Girardeau counties, Missouri, 200 miles farther south to the mouth of the river. The country thus drained is covered with a net-work of bayous and swamps, and the expansions of the streams and bayous into lakes. Probably the surface was naturally somewhat rolling, and there are now numerous ridges, usually extending in a north-and-south direction, which are entirely above overflow; but in the great earthquake of 1811 a large part of the district in the vicinity of New Madrid sank below its former level, and is now frequently submerged. These lowlands are thickly overgrown with cypress, oak, elm, ash, hickory, and willow; the soil is rich, and where above overflow produces well in corn, wheat, rye, oats, and cotton. In northeastern Arkansas the river widens into a lake some 70 miles long, and in places several miles wide.

Slope of the Saint Francis river. (*a*)

Locality.	Elevation above sea.	Fall between points.	Distance between points.	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Headwaters *	1,150			
Ironton †	887	836	130	6.43
East boundary Butler county, Missouri. †	314	153	173	0.88
Wittsburg, Arkansas ‡	161			
Mouth of river	144	17	135	0.13

* Elevation as given by Humphreys and Abbot.
† Low water at crossing of Saint Louis, Iron Mountain and Southern railway.
‡ Low water in Mississippi, by levels of precision under Mississippi River Commission.

NOTE.—The distances between points are by map measurement above Wittsburg; but the distance and fall from Wittsburg to the mouth are from the report of an examination by Mr. H. L. Koons. (See *Report Chief of Engineers*, 1871, p. 358.)

The Saint Francis is navigable for light-draught steamers, eight months in the year, to Wittsburg, but above that point its course is much obstructed by bars, snags, and overhanging trees. There are no large towns on the lower river, and the upper basin is also sparsely settled; Pilot Knob and Ironton, near the source, contain populations of about 1,400 and 800, respectively.

The upper river has a rocky bed and a quite rapid descent. At the crossing of the Iron Mountain road, on the eastern border of Butler county, there is a difference of 17 feet between high and low water, but the oscillation is probably much less farther up stream, though I do not know its amount. (*b*) This part of the river is rather inaccessible, and is only to be reached by the Saint Louis, Iron Mountain and Southern railway, which, except in the extreme upper waters, is distant 10 or 12 miles from its course. There is scarcely any use of water-power on the main river, but an occasional small mill is to be found on the little tributary creeks in Wayne, Madison, and Bollinger counties. In Madison county there is a single flouring-mill on the Saint Francis with 10 feet head and 59 horse-power, and a few miles west of Fredericktown the Silver Mountain Mining Company use 80 horse-power from the stream. They obtain a fall of 22 feet over a granite and cement dam; this structure is 24 feet wide at the base, battering to 6 feet at the top; the length of over-fall is 163 feet, and the length at base 95 feet. The breast of the dam is faced with a mass of riprap 6 feet wide at the foot and gradually thinning out toward the top.

Before reaching the region of the lowlands the river now and then cuts through rocky hills, in narrow gorges well suited to its control for power. One of these gorges occurs in Madison county, near the Einstein silver mine, and is thus described by Mr. William Einstein:

> The Saint Francis river, in its course through the northeastern part of township 33, range 5 east, cuts through granite and porphyry hills, the elevations above the river bed on either side being from 200 to about 400 feet. The bed of the river is solid rock, conforming to the hills on either side; the channel is from 100 to 150 feet in width, with an amount of water in the dryest season of the year sufficient for a very respectable power, limited only by the greater or less height of the dam. The flow of the river is steady, and in an ordinary stage will give, with 10 feet head, an important power at least ten months in the year.

Mr. Einstein further says:

> Rocky chasms, similar to the above, occur at various other places on the river, but, to my knowledge, none so favorably located. I consider these features as being very favorable for the development of power if the site selected is easy of access. Occasional floods occur, but nothing to interfere with properly-constructed works.

a This stream is 250 miles long by general course, but its actual length is probably at least twice as great.
b At Ironton the rise in Stout's creek is about 4 feet.

For a considerable distance into Wayne county the river continues rapid, with a width of 175 feet at ordinary stage, and is said to have value for power; at several points it cuts through solid ledges of rock, and occasional side channels, or sloughs, are to be found, of which advantage might be taken. Upon approaching the swamp-lands in the southern part of this county the stream becomes entirely unsuited to use, and is subject to quite heavy oscillations, which increase in the lower course to from 30 to 50 feet.

Toward its mouth the river is joined from the west by the L'Anguille, a sluggish stream flowing through swamps and lowlands. In the upper basin the principal tributaries are the Castor and Little rivers. The former and the Whitewater, a branch of Little river, furnish power to a few small mills, but they drain only limited areas before entering the lowlands.

The rainfall on the upper basins of the Saint Francis, Castor, and Whitewater, is approximately 10½ inches in spring, 10 in summer, 10 in autumn, and 9 in winter, giving 39½ inches for the year. From the even distribution of the rainfall among the seasons it is to be expected that the streams run comparatively low in summer and autumn. There being no recorded measurements of their volume, I estimate their discharge and the corresponding horse-power as below:

Estimated volume and horse-power of the upper Saint Francis river and tributaries.

Stream and locality.	Drainage area.	AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.		
Saint Francis, due west of Fredericktown, and above the Little Saint Francis.	384	90	102
Saint Francis, at southern line of Madison county	731	170	193
Saint Francis, at Greenville	1,027	240	273
Castor, at Buchanan	274	60	68
Whitewater, at Stroderville	353	80	91

Power utilized on the Saint Francis river and tributaries, with a summary for the eastern Missouri slope.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Saint Francis	Mississippi	Missouri	Madison	Flour and grist	1	10	59
Do	do	do	do	(Silver mine)	1	22	80
Sundry streams	Saint Francis	do	Stoddard	Flour and grist	1	7	20
Do	do	do	do	Saw	1	10	30
Do	do	do	Wayne	Flour and grist	4	34	68
Do	do	do	do	Flour, grist, and saw	2	26	43
Do	do	do	do	Woolen	1	5	6
Do	do	do	do	Saw	1	6	12
Do	do	do	Bollinger	Woolen	1	14	5
Do	do	do	do	Flour and grist	5	42	51
Do	do	do	Madison	do	4	36	69
Do	do	do	Iron	Woolen	1	6	8
Do	do	do	Cape Girardeau	Flour and grist	3	27	78
Do	do	do	do	Flour, grist, and saw	3	24	110
Total					29	269	639
SUMMARY.							
Meramec and tributaries	Mississippi	do			31	435½	517
Saint Francis and tributaries	do	do			29	269	639
Small streams	do	do	Shelby	Flour and grist	1	9	30
Do	do	do	Monroe	do	2	11½	44
Do	do	do	Lincoln	do	1	8	44
Do	do	do	Jefferson	do	2	40	31
Do	do	do	Saint Genevieve	do	2	20	27
Do	do	do	Perry	do	2	18	52
Do	do	do	do	Flour, grist, and saw	1	10	46
Do	do	do	do	Saw	1	11	16
Do	do	do	Saint François	Flour and grist	1	20	20
Total					73	852	1,466

VIII.—THE ARKANSAS RIVER BASIN.

The region included within the water-shed of the Arkansas river lies between the Mississippi river and the Rocky mountains, and though it stretches a long way east and west, may be said to be located, as a whole, a little south of the center of the United States. It extends from the meridian of 91° to midway between the meridians of 106° and 107°. At the source of the Arkansas river it touches latitude 39° 22′ north, while near the mouth its southern limit is latitude 33° 49′. The tract of country thus embraced has an area of about 188,000 square miles, (*a*) and is distributed among different states as follows:

	Square miles.
Colorado	28,100
New Mexico	16,900
Kansas	41,800
Indian territory	45,400
Texas	12,600
Missouri	13,700
Arkansas	29,600
Total	188,100

These areas must be regarded as only approximately correct, for the water-shed lines cannot be laid down with a certainty of their being accurate upon existing maps.

CHARACTER OF THE SURFACE.

The vast area of the Arkansas River basin presents great diversity in topography and resources. At its western boundary are the high ranges of the Rocky mountains, shutting it off from the basin of the Colorado river. In those mountains the passes range from 8,000 to 10,000 feet in elevation above sea-level, while some of the peaks tower up to heights of 14,000 feet and upward. Mount Lincoln stands directly at the source of the Arkansas river, and is more than 14,000 feet high. From this point the water-shed line extends southward along the ridge of the Sawatch mountains and Sangre de Cristo range into New Mexico; it is then continued still farther, around the headwaters of the Canadian river, by the Taos and Las Vegas ranges.

West of longitude 105° the country may be described in general as mountainous, heavily timbered, mainly with pine, and abounding in minerals, the mining of which constitutes the chief industry. Here are found extensive deposits of silver, gold, copper, lead, and coal. Notwithstanding that the mountains seem almost impassable, railroads have been built up the valleys of the streams, and the more prominent mining towns, such as Leadville, Rosita, Silver Cliff, and many others, have been rendered easily accessible.

East of the mountainous section we enter quite abruptly upon the seemingly endless rolling prairies, which stretch on to Missouri and Arkansas. For 500 to 600 miles from the mountains the country presents substantially the same general contour; there is, on the whole, an imperceptible and gradually decreasing slope away from the mountains, averaging for the whole distance not far from 8 feet to the mile. In the immediate vicinity of the mountains the natural fertility of the soil, the rapid descent and, at certain seasons, considerable volume of the streams, combine to render irrigation successful, and the soil is made to yield fine crops of wheat and other grains. Farther east, however, the soil is sandy, irrigation is less practicable, and we find a region without timber and unsuited to agriculture.

Approaching the meridian of 98° the character of the country greatly improves; timber is found to a moderate extent, the rainfall is greater, the soil is productive, and, as a rule, returns large crops of the various grains. South of the Great Bend, near the southern line of Kansas, are found large deposits of crystallized salt, in beds 6 to 28 inches thick, supposed to have resulted from the drying up of salt ponds or salt branches of the Cimarron river.

A very large portion of the Indian territory is embraced within the Arkansas basin. Corn is its main production, though wheat is also raised. It is said that cotton was formerly largely cultivated south of the Canadian and along the Arkansas and Red rivers, and some attention is still paid to it. West of the meridian of 97° a narrow belt of timber, called the Cross Timbers, stretches from the Cimarron southwesterly into Texas. West of this belt, and north of the Canadian Fork, the country is barren and unproductive, covered in places with salt and alkaline deposits. The northeastern part of the Indian territory is well timbered with cottonwood, oak, sycamore, elm, walnut, ash, and yellow pine. Considerable portions of its surface are fertile, but it contains also much poor and rocky land. Underlying it are found iron, brick-clay, and some good building stone; a valuable bed of bituminous coal extends from this section of the territory in a northeasterly direction through Missouri, passing across the adjacent corners of Kansas and Arkansas.

a Including White River basin.

Nearing the eastern border of the Indian territory we encounter a rough, mountainous section, which continues into Arkansas and Missouri. Crossing the Arkansas river near Fort Gibson, the low ranges of the Ozark mountains strike northeasterly across the corner of Arkansas, and passing through southern Missouri constitute the water-shed between the Missouri and White rivers. (*a*) These mountains abound throughout their extent in iron, lead, zinc, and other minerals, and thus contribute valuable resources to the section in which they lie. A spur, known as the Boston mountains, runs easterly into Arkansas for a considerable distance, and forms the more immediate northern water-shed of the Arkansas river. To the south of that river is the Washita range, said to be so barren in appearance that the gray sandstone of which it is composed gives the prevailing color to the landscape.

Extending from the western border of the state to Little Rock are the coal-fields of Arkansas; they lie on both sides of the Arkansas river, and embrace the greater portions of all the counties touching upon the stream in the distance mentioned. The coal is of a semi-bituminous variety and has been principally mined from the strata of the Upper Coal Measures; it occurs in veins 3 to 9 feet thick, and frequently lies less than 20 feet below the surface. In the central part of Arkansas the surface is less rough, and is largely a rolling prairie, with more or less timber interspersed. Toward the mouth of the river the country is low and heavily timbered. It has a rich, black alluvial soil, and where cultivated yields largely in cotton and corn.

The population of the Arkansas basin exhibits an important increase for the decade ending in 1880, having more than doubled.

Population of the Arkansas River basin.

[From Mr. Gannett's statistics.]

Drainage basin.	Approximate area.	Population, 1870.	Population per square mile in 1870.	Population, 1880.	Population per square mile in 1880.
	Sq. miles.				
Arkansas river	185,671	613,672	3.3	1,273,853	6.8
Cimarron river	16,632	427	.....	1,392	0.1
Canadian river	41,652	17,081	0.4	22,552	0.5
White river	29,556	291,030	9.1	461,369	15.6

The great bulk of settlement is confined to three sections along the river: The valley of the main stream and White river, in Arkansas, and southern Missouri; southern and southeastern Kansas, and the country lying toward the foot of and among the Rocky mountains.

CLIMATE.

The climate of the region which I am describing is in the main extremely healthy. The low valleys along the lower Arkansas and White rivers, like similar districts elsewhere, are visited by fevers and malarial diseases; but even there the higher lands are regarded as favorable to health, and farther westward are the elevated prairies, the value of whose dry, bracing air is everywhere known.

The winds vary considerably with location and season, but the prevailing winds of the year may be taken as lying between west and southwest, in southeastern Colorado, while for the remainder of the basin they range from southwest to southeast.

There are few long-continued records of temperature and rainfall for points in the Arkansas basin, but the ones given below, which are copied from the Smithsonian tables, will give a very good idea of those phenomena in different sections:

Locality.	Elevation.	Latitude.	Longitude.	Years of observation.	Spring.	Summer.	Autumn.	Winter.	Year.
TEMPERATURE.	*Feet.*	° ′	° ′		° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Fort Union, New Mexico	6,670	35 54	104 57	17	49.58	67.94	51.49	33.50	50.63
Fort Garland, Colorado	8,365	37 32	105 40	15	42.93	64.39	43.49	20.63	42.86
Dodge City, Kansas	2,499	37 30	100 00	*9	54.11	76.42	54.10	32.30	54.23
Fort Gibson, Indian territory	560	35 48	95 20	30	61.08	79.13	61.44	40.25	60.48
Fort Smith, Arkansas	460	35 23	94 29	19	60.79	78.48	60.65	40.55	60.12
RAINFALL.					*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Fort Union, New Mexico	6,670	35 54	104 57	17	2.12	11.92	3.73	1.32	19.09
Fort Garland, Colorado	8,365	37 32	105 40	13	3.28	6.70	2.37	2.51	14.86
Fort Larned, Kansas	1,932	38 10	98 57	11	5.17	9.63	4.95	1.67	21.42
Fort Gibson, Indian territory	560	35 48	95 20	24	11.44	9.65	9.30	6.57	36.96
Fort Smith, Arkansas	460	35 23	94 29	23	11.97	11.07	9.87	7.60	40.51

* Combined with signal-service observations.

a I am informed by Mr. James Dun, chief engineer of the Saint Louis and San Francisco railway, that in northwestern Arkansas, near the headwaters of White river, the Ozark mountains have an average elevation of about 2,200 feet above tide.

GENERAL FEATURES OF THE STREAMS.

My work in connection with the Arkansas was confined to short visits to some of the more prominent towns on the main river and its tributaries in southeastern Kansas, and to the vicinity of the headwaters of White and Black rivers in Arkansas and Missouri. My information upon other and remote portions of the basin has been derived from various sources, mainly from Humphreys and Abbot's report, and more recent reports by other government engineers of surveys and examinations of the different streams, made with a view to their improvement for navigation. (*a*)

The characteristics of some of the more important streams will be given in detail further on, but there are certain features possessed by them in common, and due to circumstances of topography, soil, and climate, which may properly come into this general description. In the upper basin of the Arkansas there are numerous streams, principally short ones, which either lie wholly in, or at least have their sources among, the mountains. In their general character as mountain streams they probably do not differ essentially from the upper tributaries of the Platte, which have been described in connection with that river, and doubtless might be used to good advantage for power in many cases if there were any demand for such use. Those which head in the mountains and find their way out into the prairies are used more or less for irrigation. The rainfall and temperature of the section drained by these mountain streams are calculated to cause large variations in their volume during different seasons of the year. The average winter temperature at Fort Garland, Colorado, is 11 degrees below freezing point, and is less than 2 degrees above freezing point at Fort Union, New Mexico, so that a large share of the precipitation of winter in the adjoining regions must be, and remain during that season, in the form of snow. At the same time the amount of winter precipitation is very small compared with that of summer. Thus at Fort Union more rain falls during the summer than in all the rest of the year, and far the greater part of the summer rain is in the two months of July and August. At Fort Garland there is a similar disproportion, though not quite so marked. It is evident, then, that the streams will run lowest in fall and winter. In spring the melting snow will swell their volumes, and during the heavy rains of summer, quickly shed from the steep slopes of the mountains, they are likely to reach their highest pitch.

Passing eastward from the mountains the rivers encountered, as far as the borders of Missouri and Arkansas, are distinctively prairie streams; they rise in the prairies, and their courses lie entirely in them. They are bordered by bottom-lands ranging from half a mile to several miles in width; in eastern Colorado and western Kansas the bottoms are rather light and sandy, but farther east are alluvial in nature. On either side there rise rounded bluffs, 50 to 300 feet high, and beyond these is the open, rolling country, the valleys of the streams being depressed below its general level. The river beds are sandy or muddy, and to a large extent are composed of quicksand. There are no abrupt falls, and the streams run smoothly, with quite uniform descent, their prevailing slope decreasing as they recede from the mountains.

The absence of rock ledges upon which to found dams is, of course, very unfavorable to the improvement of these streams for power; but it need not debar such improvement, for where crib-work or framed dams have been found impracticable on such rivers, those constructed of brush have usually met with good success. They suffer another great disadvantage, however, arising from their large variations in volume. Many of them, especially to the west of the Great Bend in Kansas, run dry every year, while others, such as the Neosho, and even the Arkansas itself, have shown the same phenomenon at intervals. These fluctuations in the streams are due, partly to the surface features of the country, and partly to peculiarities of climate. The effect which the nature of the surface has upon their steadiness may be judged from the following extract from a report by Mr. William Tweeddale, civil engineer, to the Hutchinson (Kansas) Water-Power Company; speaking of the Arkansas river, he says:

> The water-shed on either side is rolling prairie, the soil of which is mostly clayey loam intermixed with sand. For ages destitute of trees, the soil in Colorado and western Kansas, under the combined influence of rains tropical in character, high winds, and scorching southern sun, has become so compact that herbage is scant. The surface, thus unprotected, has become baked so as to be nearly impervious to water, for which reason rains do not infiltrate into the soil and form springs, but are carried at once into the water-courses. From 50 miles west of Hutchinson to the south line of the state the country is comparatively level, and the soil sandy, for which reason springs are more abundant, and the flow of the streams is plentiful and uniform.

The same unequal distribution of rainfall among the different seasons which has been noticed toward the headwaters of the Arkansas continues eastward through Kansas. Thus at Fort Larned we find the average winter rainfall to be 1.67 inches, and the summer rainfall 9.63 inches; at Fort Scott, near the eastern border of the state, the precipitation is in winter 4.79 inches, and in summer 16.37 inches. With such a comparatively heavy rainfall in the warm season, principally concentrated in the late spring and early summer, and occurring largely in the form of violent showers, which fall upon the hardened surface of the ground, nothing less could be expected than that there should be great fluctuations in the volumes of the streams. Nor is it surprising that in the late summer and autumn, when the rainfall has greatly diminished, and evaporation is still large, they should in many cases sink away in their sandy beds and disappear from sight. Over all the upper Arkansas basin the evaporation must be great; the prevailing winds are west to southwest, and, having been stripped of their moisture beyond the mountains, seek to replenish their store from the country to the east.

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a From Captain Thomas H. Handbury, corps of engineers, I received much information regarding the lower Arkansas river. Many railroads supplied lists of elevations on their lines, and to Mr. H. V. Hinckley, assistant engineer of the Atchison, Topeka and Santa Fé railroad, I am especially indebted for the altitudes of a large number of points on the main and branch lines of that company.

Southeastern Kansas is the portion of the Arkansas basin in which there is the most use of water-power, though it is quite limited even there. In recent years there has been a large emigration to that section, resulting in a much increased cultivation of the soil; new railroads have been constructed, giving good facilities for transportation, and many flouring-mills have been built, which have availed themselves of the natural power afforded by the rivers and minor streams. Very many available sites still remain undeveloped, though I am unable to mention them in detail, as might be practicable with rivers of a different nature. These prairie streams preserve essentially the same features throughout, and, generally speaking, if they have any value for power, they can be improved at short intervals all along their courses, certain local advantages determining the selection of one point or another. When possible, the total fall in different sections of the streams will be given; the power utilized in the successive counties will appear in a subsequent table; and by comparison of these two sets of data some idea may be formed of the extent to which the streams will still admit of improvement.

Passing eastward into Arkansas and Missouri we encounter, successively, mountain and prairie streams, and, approaching the Mississippi, sluggish rivers and bayous entirely valueless for water-power. The streams of the first two classes would, no doubt, furnish many good powers of moderate size, though they are unreliable in flow. The section in which they lie is sparsely settled, and very deficient in railroad facilities; naturally there is but little demand for power, and they are scarcely at all utilized.

An increase of storage capacity beyond that afforded by the mill-ponds along the streams is, in general, impracticable in the Arkansas basin. There are no lakes or ponds, worth mentioning, to be raised by dams, and though, in the mountainous section near the headwaters, and again in Arkansas and southern Missouri, dams might be thrown across favorable ravines and a limited amount of storage developed, yet in the open prairies there are few such opportunities. The side streams are small; it is difficult to find suitable foundations for high and strong dams; and if the reservoirs were permitted to spread much beyond the natural banks heavy damages might be incurred from the submergence of rich bottom-lands.

IX.—THE ARKANSAS RIVER.

The Arkansas river has its source in the central part of the state of Colorado, in latitude 39° 22′, and longitude 106° 12′. Its course is in the main southeasterly, and passes successively through southeastern Colorado, portions of Kansas and the Indian territory, and the state of Arkansas. In Desha county of the latter state it empties into the Mississippi, about 700 miles above the mouth of that river. It measures 1,100 miles along its general course from source to mouth, but its actual length is much greater. The old mouth of the river was at Napoleon, and at high stages more or less water is still discharged at that point through its former channel; but ordinarily its main volume flows through a bayou or cut-off, several miles above, into White river, and so in a manner reduces that stream from the position of an independent river to that of a tributary of the Arkansas. Inclusive of White river, the Arkansas drains an area of about 188,000 square miles, or, without that stream, about 160,000 square miles.

For its first 120 miles the river is a mountain torrent, flowing over a rocky bed, with clear waters and rapid descent. Above Cleora the area drained varies from 10 to 35 miles in width, and is hemmed in by mountains, down the sides of which tumble numerous little streams making their way to the main river. The elevation of the latter is reduced from about 10,000 feet at the head to less than 5,400 at Cañon City; in other words, the river loses nearly one-half its elevation in 120 miles from the source. The Denver and Rio Grande narrow-gauge railroad follows closely this portion of the river to the headwaters.

In the vicinity of Cañon City the Arkansas makes its escape from the mountains, after passing through a magnificent gorge, or cañon, in which it descends more than 300 feet. From Cañon City to Pueblo, a distance of about 41 miles, the average descent is not far from 16 feet to the mile. For the greater part of this distance the river averages 175 feet in width, and is 3 to 5 feet deep. Pueblo is the most important city in this section, and has a population of about 3,200. From Pueblo to the eastern boundary of Colorado, the principal tributaries of the Arkansas are, in order, from the north, Fountain qui Bouille, Chico, Horse, and Big Sandy creeks; and from the south, Huerfano river, Purgatoire river, and Two Butte creek. The general course of the stream is, in this distance, easterly, running 70 to 80 miles above the south line of the state.

Entering Kansas, the river runs for 140 miles, by general course, in a direction a little south of east; it then makes a bold curve to the northward, forming what is known as the Great Bend, after which it flows southeasterly. From Pueblo to the Great Bend, its width seldom exceeds 450 feet. The slope gradually decreases from nearly 15 to between 6 and 7 feet per mile. A single flouring-mill is returned as using the stream for power in Pueblo county, but further than that it is unemployed in this section. The bed is, to a large extent, quicksand; the stream itself is shallow, and inclosed by low banks, beyond which spreads a grassy bottom half a mile to 2 miles in width between bluffs. The latter rise 50 to 300 feet high above the stream, and are succeeded by the undulating surface of the prairie.

The peculiar features of this portion of the river and the adjoining valley are thus described by Mr. Tweeddale:

The bed is sand; the banks are low, but well defined, being somewhat rolling, with an inclination toward the river, as well as in the direction of its flow. * * * The soil of the valley is of Drift formation, formed of the detritus of the Rocky mountains, and is of varying character, with a predominance of sandy loam. The subsoil is mostly sand and gravel, and while the melting of mountain snows in June and July keeps the river banks full, the addition of storm waters of the violent rains in Colorado, amounting at times to from 2 to 3 inches in one hour, and which, falling upon an impervious water-shed, raise its tributaries, Purgatoire, Rule, Muddy, and Sand creeks several feet in an hour, does not cause the Arkansas river in Kansas to overflow even its low banks. The surplus water spreads out laterally, and is stored subterraneously in the adjacent porous subsoil. The same conditions exist with its tributaries in Kansas, particularly Pawnee, Walnut, and Cow creeks. To this is added the further peculiarity that while the streams in the Arkansas valley are relieved of their surplus waters by adjacent porous subsoil, the subsoil is in turn drained by the streams. Of this Cow creek is an instance, draining not only the subsoil, but also through it the Arkansas river.

As indicating the existence of this substratum of sand beneath the surrounding valley and continuous with the bed of the river, it is stated that wells sunk in the bottom-land strike water at the level of that in the Arkansas, and rise and fall with that stream.

Occasionally the Arkansas runs dry, although this has happened but once in the past five years. The last occurrence was in the spring, and, without any apparent cause, was followed by a sudden restoration of flow, which continued through the year. On such occasions as this the river is literally dry, there being very few pools, even, to be seen. The stretch most affected appears to be that between Sequoyah and Sedgwick counties, Kansas.

The principal tributaries received in Kansas are: From the north, Pawnee Fork, Walnut creek (of Barton county), Cow creek, Little Arkansas, Walnut creek (of Cowley county), and Grouse creek; from the south, Rattlesnake creek, Ne-Ne-Squaw river, and Slate creek. South of the Arkansas, near the Colorado line, Bear creek runs northeasterly toward the main stream, through Stanton county, but comes to an end 8 or 10 miles south of the river. Similarly, to the north, Poison creek runs easterly through Greeley and Wichita counties, but terminates its course in a basin or depression near the center of Scott county; its general direction is toward the headwaters of Pawnee Fork and Walnut creek, but whether there is any evidence of an underground connection with those streams I cannot say.

The Atchison, Topeka and Santa Fé railroad follows the river closely from Pueblo to Hutchinson, and then strikes off to the northeast toward the Missouri river. Along its course are numerous thriving towns, such as Dodge City, Larned, Great Bend, and Hutchinson, with populations of 1,000 to 1,500; farther down the river are Wichita, 4,900 inhabitants; Winfield, 2,800, and Arkansas City, 1,000.

East of Fort Dodge the country rapidly improves in fertility and in the extent of cultivation; while in 1878 Ford county showed less than half of 1 per cent. of its surface under cultivation, Reno county returned 17 per cent., Sedgwick 28 per cent., and Cowley 21 per cent. cultivated. (*a*) The principal productions in this section are winter wheat, corn, oats, and grass.

At Hutchinson, in Reno county; at Oxford, in Sumner county, and at Arkansas City, in Cowley county, the river is drawn upon for power, and these are the only points east of Pueblo county, Colorado, at which it is so employed; these powers will be described later in detail.

From Wichita to Arkansas City a thin growth of cottonwood and willows constitutes about all the timber that is to be found along the stream. The bed is largely of quicksand. In the vicinity of Wichita the river is 600 to 800 feet wide, and has a slope of about 3 feet to the mile. Passing down stream from Arkansas City more timber is found, comprising oak, hickory, pecan, walnut, hackberry, and on the low grounds close to the stream abundance of cottonwood. The banks and bluffs become high and rocky, and the river bed is more contracted. Toward the mouth of the Cimarron it grows wide and sandy again, and in places attains a width of 2,000 feet. (*b*) Of this part of the river Captain Bell, who led a detachment down its course in 1820, wrote:

Below the Cimarron we were all immediately struck with the change in the appearance of the water of the river. No longer of that pale clay color to which we have been accustomed, it has now assumed a reddish hue, hardly unlike that of the blood of the human arteries, and is still perfectly opaque, from the quantity of an earthy substance of this tint which it holds in suspension; its banks and bars are, from deposition, of the same color.

The river passes through the Indian territory in a tortuous southeasterly course, its slope gradually decreasing to less than 2 feet per mile. It receives numerous important accessions from tributaries, of which the principal are: On the east, Buck creek, Verdigris river, Grand or Neosho river, and Illinois river; on the west, Salt Fork, Red Rock creek, Black Bear creek, Cimarron river, Elk creek, Canadian river (the largest tributary), Sans Bois creek, and Poteau river.

The lower course of the Arkansas is bordered by wide alluvial bottoms, subject to overflow unless protected by levees. At Little Rock there is to be seen, on the north side of the river, a high rocky bluff of dark-colored slate, and a mile or two below on the south side a similar but much smaller exposure. These are called, respectively, the Big Rock and Little Rock, and are the last exposures on the river. Below Little Rock the Arkansas valley soon merges in the wide valley of the Mississippi. Below Fort Smith the chief tributaries are Lee's, Mulberry, Piney, Point Remove, and Cadron creeks on the north; and on the south side, Petit Jean and Fourche la Fave creeks.

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a Report Kansas State Board of Agriculture.

b See report of reconnaissance by J. D. McKown, *Report Chief of Engineers*, 1879.

Elevations and slope of the Arkansas river.

Locality.	Elevation above sea.	Distance between points.	Fall between points.	Fall between points.
	Feet.	*Miles.*	*Feet.*	*Ft. per mile.*
Source of river *	10,000			
		67	2,950	44.03
Cleora †	7,050			
		48	1,674	34.87
Cañon City †	5,376			
		40	663	16.57
Pueblo ‡	4,713			
		152	1,245	8.19
Granada ‡	3,468			
		133	969	7.29
Dodge City ‡	2,499			
		195	1,275	6.54
Wichita §	1,224			
		65	179	2.75
Arkansas City §	1,045			
		106	246	2.32
Mouth of Salt Creek §	799			
		77	145	1.88
Mouth of Cimarron river §	654			
		84	149	1.77
Near Fort Gibson ‖	505			
		127	122	0.96
Van Buren (7 miles below Fort Smith) ¶	383			
		265	161	0.61
Little Rock **	222			
		250	115	0.46
Mouth of river ††	107			

* Elevation as given by Humphreys and Abbot.
† Level of rails, Denver and Rio Grande railway.
‡ Level of rails, Atchison, Topeka and Santa Fé railroad.
§ Level of water surface. Distances and fall between stations from report of J. D. McKown. (See *Report Chief of Engineers*, 1879.)
‖ Low water at Missouri, Kansas, and Texas railway crossing.
¶ Low water by levels Saint Louis and San Francisco railway.
** Low water by levels Saint Louis, Iron Mountain and Southern railway.
†† Low water in Mississippi river. Levels of precision under Mississippi River Commission.

NOTE.—Distances above Wichita are measured upon land-office maps; distances below Fort Gibson are as given by Humphreys and Abbot.

I have but few data concerning the actual volume of the Arkansas. Major Suter states that the ordinary low-water discharge at the mouth, exclusive of White river, may be taken as approximately 3,000 cubic feet per second, and the ordinary high-water discharge as about 70,000 cubic feet per second.

Mr. McKown, in his report of a reconnaissance between Wichita and Fort Smith, gives the discharge at Arkansas City, in a very low stage, as about 675 cubic feet per second.

I was informed by Mr. Knight, consulting engineer of the works at Arkansas City, that the discharge assumed by him was about 600 cubic feet per second at extreme low water.

On the 5th of December, 1875, the volume at Hutchinson was measured by Mr. Tweeddale, and found to be about 1,500 cubic feet per second. The stage of river was described as "ordinary low water, 5 feet below high water", and it was stated that only in one or two instances during five years had the river been much lower.

The results of these different measurements may be thus summed up:

Discharge of the Arkansas river.

Locality.	Drainage area.	Volume, cubic feet per second.	Cubic feet per second per square mile.	Remarks.
	Sq. miles.			
Hutchinson, Kansas	39,000	1,500	0.039	Mr. Tweeddale's measurement; 5 feet below high water.
Arkansas City	44,500	600	0.014	Assumed by Mr. Knight; extreme low water.
Do	44,500	675	0.015	Measured by J. D. McKown; very low stage.
Mouth of river	160,000	3,000	0.019	Ordinary low water as estimated by Major Suter.
Do	160,000	70,000	0.437	Ordinary high water as estimated by Major Suter.

Considering that, in the Great Bend and above, the Arkansas has occasionally run dry, its volume in a low stage is evidently an uncertain quantity; it is probable, however, that over the section from Hutchinson to Arkansas City a volume of 600 to 1,000 cubic feet per second may safely be relied upon throughout all ordinary years.

The river is subject to three floods during the year—the first in January or February, the second in June or July, and the third in November; the second of these is the highest. In the upper river the slope is sufficient to pass the volume of water found there without overflow of the banks, and the range between high and low water is small, being only 7.45 feet at Wichita. The lower river has a moderate slope only, and there the oscillations are large. Toward the mouth the ordinary range between high and low water is 26 feet, and the extreme range 45 feet. At Little Rock the rise during the flood of 1844 was 33 feet.

Navigation is practically confined to the section between Fort Gibson and the mouth. Even there it is uncertain, in some years being good for eight months, while at other times low water has forced a suspension during an entire year. Aside from low water the most serious hindrance to navigation is from snags, which are contributed by the caving banks. In 1875 and 1878 successful attempts were made by private individuals in southern Kansas to transport grain down the river, and two or three trips were made in safety to Little Rock by small light-draught steamers. The portion of the river between Wichita and Fort Smith is so wide and shallow that its improvement for navigation would be difficult and expensive; the cost was estimated at $900,000 by Mr. McKown, assistant engineer (see *Report Chief of Engineers*, 1879).

Drainage areas of the Arkansas river.

Locality.	Square miles.	Locality.	Square miles.
Granite	391	Arkansas City, above Walnut creek	44, 502
Helena, above Trout creek	778	Below Salt Fork	54, 417
Cleora	1, 440	Below Cimarron river	75, 048
Cañon City, below Grape creek	3, 051	Below Verdigris river	84, 662
Pueblo, below Fountain creek	5, 611	Below Neosho river	97, 408
West Las Animas, above Purgatoire river	13, 844	Below Canadian river	145, 983
Granada, above Granada creek	23, 086	Fort Smith, below Poteau river	149, 265
Dodge City, including Poison Fork	29, 238	Little Rock	157, 466
Hutchinson, above Cow creek, but including Poison Fork	39, 009	Pine Bluff	158, 329
Wichita, below Little Arkansas	41, 347	Mouth, not including White river	160, 218
Oxford	44, 036	Mouth, including White river	188, 143

Ascending the river, the first and most important development of power on its course is met at Arkansas City, 4 miles north of the boundary of the Indian territory. It is a place of about 1,000 inhabitants, an important shipping point for Indian supplies, and is reached by a line of the Atchison, Topeka and Santa Fé railroad. The city lies upon the left of the Arkansas, on a point of bluffs formed where the valley of Walnut creek merges in that of the main stream. At very low stages the width of running water here does not exceed 200 feet; in a medium stage the river is 1,000 feet wide, and is confined between low banks 5 or 6 feet high. Farther back are the high banks, rising some 30 feet, and separated from each other by a total distance of 1,500 feet. The river bed is composed of quicksand 9 to 10 feet deep, underlaid by limestone of poor quality. The fall at this locality is about 2½ feet per mile.

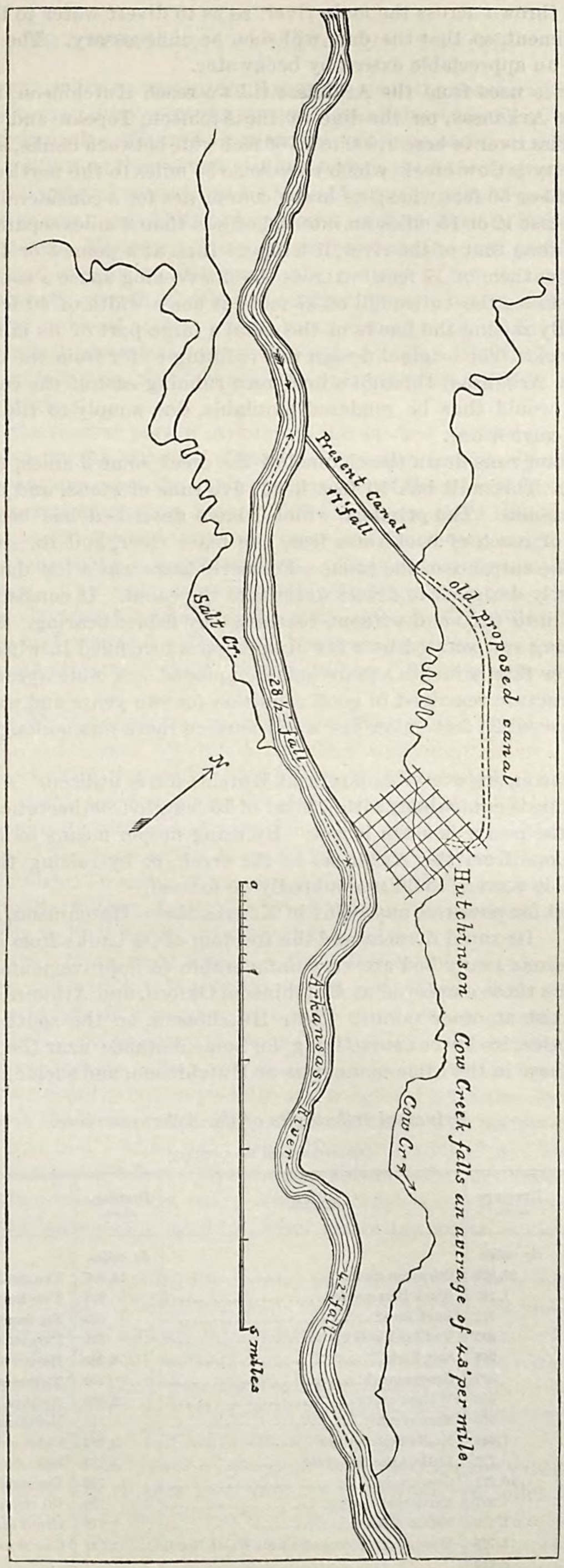
It was known for many years that there was a considerable difference of level between the river and the creek at points opposite the city, and by use of a carpenter's level the fall was determined to be 35 feet. A company was formed, and a consulting engineer engaged. An accurate line of levels was then run, and the fall found to be—not 35 feet—but a little more than 20 feet. The enterprise of developing the power was begun, however, and when the locality was visited by me, in the spring of 1881, was well under way. The general design includes a dam across the Arkansas, and a canal running thence, around the edge of the bluffs on which the city is built, to Walnut creek.

The dam is to be 700 feet long, 4 feet high, 44 feet wide at the base, and 12 feet wide at the top, and to consist of brush mattresses, arranged in successive layers. The mattresses used are 16 feet long, 4 feet wide, and 1 foot thick, the brush being bound in layers by short lengths of sapling which are wired together at their ends. The breast of the dam will be formed by a series of off-sets; the lowest of these is to be 12 feet, and this with the succeeding one of 8 feet will constitute an apron projecting 20 feet down stream. The two remaining off-sets are to be 1 foot each. Intermingled with the brush of the mattresses are hay and straw, designed to catch sediment, of which the Arkansas transports a large amount, and so render the structure compact and tight. It is expected that as the sand shall be scoured out from under the apron the latter, and possibly the entire dam, will gradually settle toward a firm bearing on bed rock.

The canal is designed to be about 2½ miles long, 4 feet deep, 15 feet wide at the base, and 27 feet wide at the top. It will have a grade of 2 feet to the mile, and an estimated capacity of 260 cubic feet of water per second. After allowing for the grade of the canal there remains an effective head of 19 feet, equivalent, with the above volume, to 560 theoretical horse-power. This will accommodate five or six flouring-mills carrying as many as five runs of stone each. But a small part of the ordinary flow of the river is thus utilized. By measurements previously given it is seen that even in unusually low water a discharge of between 600 and 700 cubic feet per second may be relied upon, or more than twice the estimated capacity of the present canal.

Although at the time of my visit the improvements had not been completed, the erection of one flouring-mill had already been decided upon by parties from Illinois, and it was desired to attract as many other establishments as possible to this point. The locality is well situated, in a good winter-wheat region; the climate is mild, rendering out-door labor possible throughout the year, and abundant supplies of wool are to be obtained near at hand.

The next power on the river is at Oxford, a small place of 400 inhabitants, about 40 miles below Wichita, on the west bank. The mill is located on an old slough and obtains a head of 10 feet, but uses only a small portion of the available power; it carries five runs of stone and has a capacity of 150 barrels of flour per day. The slough is 2½ miles long, the lower half mile serving as tail-race; having become somewhat filled with sediment, a low rude



WATER PRIVILEGE AT HUTCHINSON.

dam of brush and stone was thrown across the main river, so as to divert water to the mill; the effect has been to scour out the deposit of sediment, so that the dam will soon be unnecessary. The mill is entirely out of reach of floods, and is not troubled to an appreciable extent by backwater.

Above Oxford no power is used from the Arkansas till we reach Hutchinson, in Reno county. This city lies upon the north bank of the Arkansas, on the line of the Atchison, Topeka and Santa Fé railroad, and has a population of about 1,500. The river is here 1,600 to 1,700 feet wide between banks, and has a fall of over 5 feet per mile. Passing through the city is Cow creek, which rises some 55 miles to the northwest, in Barton county. It is a small, crooked stream, only 40 or 50 feet wide; its lower course lies for a considerable distance in the bottom-land of the Arkansas, and for the last 12 or 15 miles an interval of less than 2 miles separates the streams. The descent of the creek being less rapid than that of the river, it happens that, at a point 3 or 4 miles above Hutchinson, there is a difference of level between them of 17 feet. Across the intervening space a canal has been dug, about 2 miles long and using up in this distance the entire fall of 17 feet; it has a width of 40 feet, and with its large slope the water has a rapid current. By raising the banks of the canal a large part of its fall could be utilized for power at the point of entering Cow creek. The original design was to bring water from the creek (re-enforced, if necessary, by means of a canal from the Arkansas) through a long race running east of the course of the former stream. It is said that a fall of 16 feet would thus be rendered available, due simply to the natural descent of the creek. This plan was not, however, carried out.

As now arranged, the water runs down the channel of the creek some 3 miles, to what is known as the "First Water-Mill", at Hutchinson. This mill has 10 feet head, five runs of stone, and uses 60 horse-power. Power is also employed by a small corn-mill. The privilege which I have described has been easily improved, and is well situated. It is entirely out of reach of backwater from the main river, and its supply from that source is easily controlled by head-gates at the entrance of the canal. Formerly there was a low dam across the river at that point, only 18 inches high, and merely designed to divert water into the canal. It consisted of two rows of sheet-piling, 10 feet apart, simply driven into the sand without reaching any firmer bearing. They were joined at the top by capping pieces, the whole being surmounted by a low framed structure filled in with stone. The dam was of light construction, no timbers larger than 4 inches square being employed. A rude apron of plank protected the river bed below the dam. The structure remained in good condition for two years and was then partially carried away; but as the head-gates now opened 2½ feet below the water surface there was no longer any necessity for a dam, and it was entirely removed.

But a small fraction of the entire available power at Hutchinson is utilized. Assuming a low-water discharge of 600 cubic feet per second, this is equivalent, with a head of 10 feet, to 680 theoretical horse-power; and during the greater portion of the year the power is much larger. By using proper means to divert water into a canal, which should run with moderate slope from the Arkansas to the creek, or by raising the banks of the present canal sufficiently, a series of valuable powers could undoubtedly be formed.

The Arkansas is not used for power at any point in Kansas above Hutchinson, and only two mills are returned upon the stream in Colorado. Its rapid descent and the freedom of its banks from overflow are advantageous, but the wide channel and treacherous sandy bed are very unfavorable to improvements for power. The best methods of using the stream seem to be those employed at Hutchinson, Oxford, and Arkansas City, and it is not improbable that similar opportunities exist at other points. Near Hutchinson, on the south side of the Arkansas, a small stream called Salt creek empties, its lower course lying for some distance near the main river. It is claimed that a power might be developed there in the same manner as at Hutchinson, and such an improvement has, indeed, been discussed.

Principal tributaries of the Arkansas river.

[In order from the mouth.]

Stream.	Drainage area.	Stream.	Drainage area.	Stream.	Drainage area.
	Sq. miles.		*Sq. miles.*		*Sq. miles.*
White river	27,925	Cimarron river	18,497	Pawnee Fork	2,633
Fourche la Fave creek	1,133	Black Bear creek	628	Two Butte creek	1,217
Cadron creek	772	Buck creek	295	Big Sandy creek	3,722
Point Remove creek	495	Red Rock creek	514	Purgatoire river	3,092
Petit Jean creek	968	Salt Fork	6,940	Horse creek	1,310
Illinois creek	392	Grouse creek	401	Timpas creek	459
Piney creek	550	Walnut creek	2,005	Apishpa river	1,156
Mulberry river	469	Slate creek	315	Huerfano river	1,791
Poteau river	1,668	Ne-Ne-Squaw river	2,282	Chico creek	833
San Bois creek	727	Little Arkansas river	1,287	Saint Charles river	562
Canadian river	46,221	Cow creek	709	Fountain qui Bouille creek	981
Elk creek	387	Rattlesnake creek	720	Oil creek	432
Illinois river	1,470	Poison creek*	1,719	Grape creek	536
Neosho river	12,746	Walnut creek (empties near Great Bend)	1,784	Currant creek	310
Verdigris river	8,010				

*Does not reach the main river.

THE WHITE RIVER AND TRIBUTARIES.

The main fork of White river rises in northwestern Arkansas, near the southern boundary of Madison county. The river pursues a very crooked course, and leaves the state at a point about 50 miles due north of its source; flowing through Barry, Stone, and Taney counties, Missouri, it re-enters Arkansas about 40 miles east of the locality where it previously left the state, and continuing thence in a southeasterly and southerly direction joins the Arkansas near its mouth. It is 360 miles long by general course, but its actual length is probably more than twice as great.

The area drained by this river comprises 27,925 square miles, and includes a large part of northern Arkansas and an important section in southern Missouri. Three varieties of surface are presented—lowland, prairie, and mountains. For 80 miles, more or less, above the mouth the country is low, swampy, and subject to frequent overflows. It is covered with a heavy growth of oak, ash, walnut, poplar, beech, and gum. The soil is rich, and, where above overflow, yields fine crops of cotton, wheat, corn, rye, and oats. To the west of this section the country becomes hilly, and is in part timbered and in part an open prairie. The timber is mainly hard wood. The bottoms are very productive in cotton, corn, and tobacco; the uplands are less fertile, but are well suited to grain, and are especially valuable for grazing.

Advancing westward from the central part of Arkansas, the surface grows more and more hilly, then quite rough and broken, and finally rises to the summits of the Ozark mountains, among which White river heads and runs its upper course. These mountains cross the northwestern part of the state, and then extend easterly through southern Missouri. They seldom rise more than 500 to 1,000 feet above their bases, or more than 1,500 to 2,000 feet above sea-level. They do not exist throughout as a regular and continuous range, but largely as disconnected knobs and peaks, with frequently very rocky, precipitous slopes. They are chiefly composed of limestone, sandstone, granite, greenstone, and clay slate. The main ridge is thickly timbered with oak, while south of it, in Missouri, there is a great deal of pine. The elevated districts comprising this portion of the White River basin have a healthful climate, but generally a shallow and poor soil. They are, however, very rich in mineral resources, such as iron, lead, and zinc, and contain deposits of copper, nickel, cobalt, and tin. The streams are clear, cool, swift-running, and well sustained by springs.

According to the statistics of Mr. Gannett, the population of White River basin increased from about 291,000 in 1870, to about 461,000 in 1880. Advancing up stream the more important towns on the river are: Augusta, population about 700; Jacksonport, 700; Batesville, 1,300; Forsyth, 300; and Fayetteville, 1,800. It is seen that, considering the length of river, there are few places of much consequence. The greater part of the country drained by this river is, in fact, sparsely settled and very difficult of access. The Memphis and Little Rock, and the Saint Louis, Iron Mountain and Southern railroads cross the lower river; in Missouri, the Saint Louis and San Francisco line approaches within about 30 miles of its course, and a partially-completed branch of the same road passes southerly through Fayetteville, follows closely the West Fork of White river, and after piercing the Boston mountains continues southwesterly to Fort Smith, on the Arkansas river.

Above Forsyth White river is a clear, rapid stream. Its valley is contracted, the bottom-land narrow and showing but few spots suited to cultivation. The banks are of good height, with frequent rock exposures; the bed is generally rocky, consisting mainly of limestone, with more or less cherty quartz. The river is in this section 200 to 300 feet wide, 2 to 5 feet deep in an ordinary stage, and is a constant succession of shoals, but without any abrupt falls. It is subject to heavy freshets, with a rise of 10 to 12 feet above low water.

Below Forsyth the neighboring country continues hilly and rough for 200 miles down stream, or to the vicinity of Batesville. "The hills and rock bluffs are very high and precipitous. The bottom-lands are narrow, generally upon one side of the river at a time, and seldom over one-half mile in width." (*a*) The banks are firm, and the width of the stream at low water is about 400 feet. There are no abrupt falls, but occasional rocky shoals with a few feet of descent. At Elbow shoals, some 50 miles below Forsyth, there is an estimated fall of 4 feet in 1,000 feet. In this portion of White river the bottom-land is 20 to 25 feet above low water, while the extreme freshet rise is reported to be 28 feet.

Below Jacksonport, and thence to the mouth, the country adjoining the river is low, and during high water is submerged to a depth of from 3 to 10 feet. The bottom-lands are cultivated in some places, but they usually display a heavy growth of timber and cane-brakes, and are intersected by many bayous and swamps. The average width of this portion of the stream varies for different sections from 350 to 500 feet. The highest recorded rises in White river have been those of 1844 and 1867. The top of the 1844 flood was 27 feet above low water at Saint Charles; in 1867 the river rose 29½ feet at that point, and 29¼ feet at Jacksonport, overflowing the latter town 2 feet, and the adjacent country 3 to 10 feet, in depth. Lowest water usually occurs in July, August, and September; the regular rises are in spring and fall, and a fair stage of water prevails through the winter.

With an ordinary depth of water the river is navigable to Batesville, 380 miles by water from the mouth. Contemplated improvements will soon, it is thought, extend navigation nearly to the mouth of Buffalo Fork, and afford an outlet to what is known as the Yellville country. Eventually navigation may be carried to Forsyth, 590

a See report by A. Livermore, *Report Chief of Engineers*, 1871.

miles from the mouth. Below Jacksonport the chief obstructions are occasional gravel shoals, snags, and some wrecks. Between Jacksonport and Forsyth there are more or less snags and overhanging trees, but the most serious obstructions are a series of rocky shoals. At Buffalo shoals, the worst of these, work was begun by Major Suter in 1878, the design being to increase the depth at the shallowest points by building seven spur-dikes of stone, and in the *Chief of Engineers' Report* for 1880 three of these are stated to have been completed, with good results.

Elevations and slope of the White river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Head of West Fork †	1,898			
		625	80	7.81
Range 30, township 15, section 32 ‡	1,273			
		708	177	4.00
Forsyth §	565			
		152	100	1.52
Point 490 miles from mouth §	413			
		143	100	1.43
Point 390 miles from mouth §	270			
		77	60	1.28
South of Jacksonport ‖	193			
		86	**330	0.26
Mouth of river ¶	107			

* By map measurement above Forsyth; below that point as given by government engineers.
† Top of gap in Boston mountains, tunneled by Saint Louis and San Francisco railway, range 30, township 13, section 13.
‡ Low water by Saint Louis and San Francisco railway levels.
§ Distances and elevations as estimated by Mr. Livermore, in report previously referred to; elevations unreliable.
‖ Low water at Saint Louis, Iron Mountain and Southern railway crossing.
¶ Low water in Mississippi river by levels of precision under Mississippi River Commission.
** Approximate.

There are no long-continued records of rainfall at points in the White River basin, but from the Smithsonian rain-charts I should estimate the average downfall for the entire basin at about 13½ inches in spring, 11 in summer, 10 in autumn, 9 in winter, and 43½ for the year. The amount for the upper basin seems to be slightly less in each of the seasons, and is about 39½ inches for the year. No accurate determinations have been made of the volume of flow in the river. Major Suter states that the discharge in ordinary low water may be taken as approximately 3,000 cubic feet per second near the mouth, and 50,000 cubic feet per second in ordinary high water. During the examination of the upper river in 1870 its volume was measured by Mr. A. Livermore, assistant engineer, and found to be 264 cubic feet per second at a point 67 miles, by river, below Forsyth. These various results may be thus presented:

Discharge of the White river.

Locality.	Drainage area.	Volume, cubic feet per second.	Cubic feet per second per square mile.	Remarks.
	Sq. miles.			
Mouth of river	27,925	3,000	0.1074	Ordinary low water, as estimated by Major Suter.
Mouth of river	27,925	50,000	1.7910	Ordinary high water, as estimated by Major Suter.
Sixty-seven miles below Forsyth	5,511	264	0.0480	Measurement by A. Livermore. River said to have been lower at the time than ever before.

The meager railroad facilities, and lack of time for slower methods of traveling, prevented me from gaining full information as to the value for power either of the main river or most of its tributaries. I judge, however, that the upper portion of White river presents real advantages for use in its rocky bed and banks, considerable fall, and a volume of fair size. The freshet rises are sudden and large, but probably no more serious than on many rivers in extensive use. Hitherto there has been no demand for power in this section, except by occasional small saw- or grist-mills, and these have been located upon the little streams, which are more easily and cheaply controlled than the main river. The difficulty of access, and sparse settlement, have also been hindrances to development, but will gradually disappear, as the country is being opened up by the Saint Louis and San Francisco railway extension. The famous Eureka Springs have already attracted a population forming an important town. The only mills on White river are a small flouring- and grist-mill in Benton county, and a flouring-, grist-, and saw-mill in Madison county. There are a great many mills on the various tributaries, as shown in the table of utilized powers, but they are all of small size. Those streams draining the slopes of the Ozark mountains are probably the most reliable and valuable of all the tributaries, while those farther down stream, in eastern Arkansas, are sluggish and of little use.

Estimated volume and horse-power of the upper White river.

Locality.	Drainage area.*	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Below War Eagle Fork	979	40	45	70	80	150	170
Below King's river	2,095	80	91	150	170	310	352
Below James' Fork	3,539	150	170	280	318	560	636
Forsyth, below Swan creek	4,463	200	227	350	398	700	795

* Drainage area below Crooked creek, 6,576 square miles; below Buffalo Fork, 7,955 square miles; below Black river, 20,734 square miles.
NOTE.—Rainfall on the upper basin about 12½ inches in spring, 10 in summer, 9½ in autumn, 7½ in winter, and 39½ for the year.

Drainage areas of the principal tributaries of the White river.

Stream.	Drainage area.	Stream.	Drainage area.
	Sq. miles.		*Sq. miles.*
La Grue river	567	Buffalo Fork	1,346
Big creek	850	Crooked creek	454
Cache river	1,905	Big Beaver creek	435
Bayou des Arcs	717	Long creek	318
Little Red river	1,243	James' Fork	1,354
Black river	8,810	King's river	610
Old Fork	687	War Eagle Fork	344
Big North Fork	1,800	Main and West Forks, above War Eagle Fork	635

La Grue river drains portions of Prairie and Arkansas counties, and enters White river from the west. Its upper course is through what is called Grand prairie, said to be almost destitute of springs.

Big creek runs through a low region on the east side of the main river, heavily timbered, swampy, and subject to overflow.

Cache river drains a long narrow strip, similar in character to the country just described.

Little Red river (*a*) runs easterly through Van Buren county, and southeasterly through White county, emptying into White river from the west. It is about 95 miles long by general course, and drains a rolling prairie surface with considerable timber. For nine months in the year small boats can ascend the river 30 miles, to West Point, and during three of those months advance 18 miles farther, to Searcy Landing. At a low stage the amount of water flowing is small, and navigation is obstructed by shoals, snags, and leaning trees. From Searcy Landing to West Point the river bed is generally rocky, with several shoals, varying from 130 feet in length, with 2.05 feet fall, to a mile and a half in length, with 0.8 foot fall. The stream is in this section 250 to 300 feet wide between banks, with a low-water depth of 3 to 9 inches on the shoals. Between the shoals are pools, some miles in length, with sandy bed and a depth of 2 to 16 feet. The banks are wooded, composed of firm clay, and range from 25 to 45 feet in height above low water. In places where the river approaches the bluffs the banks are rocky, steep, and high. The country adjoining the lower river is heavily wooded, and is overflowed during high water.

Low water occurs in July, August, and September. A freshet rise of short duration takes place in spring, usually in May or the latter part of April, and there are occasional short rises in fall and winter. The oscillations are often very rapid, and it is said that the river will sometimes rise 15 or 20 feet in twelve hours, and again within an equal length of time regain its former level. The highest recorded freshet was that of 1867, when the rise was 39.3 feet at Searcy Landing, and 29.3 feet at West Point.

THE BLACK RIVER.

Black river is the principal tributary of the White, having a length, by general course, of about 170 miles, and a drainage area of 8,810 square miles. Its source is in Iron county, Missouri, a short distance west of the headwaters of the Saint Francis, and the two streams run approximately parallel. Black river empties into the main stream in Jackson county, at the point where the latter changes its course from southeast to south. After entering Arkansas it receives several tributary streams from the northwest, which also head in southeastern Missouri, and which, together with the main Black, drain the southern slope of the Ozark mountains. This portion of the basin is rough and broken, well-timbered with pine and oak, and contains valuable deposits of iron, lead, copper, and

a Information obtained from report by Mr. Justin Straszer. See *Report Chief of Engineers* for 1871.

zinc. The lower river is very winding, and runs through low bottom-lands subject to overflow; the high lands beyond are cultivated and yield good crops of cotton. The valley is thickly timbered with cypress, white oak, black walnut, and, in Missouri, poplar.

The river is navigable to Corning in ordinary water, and it is designed to extend navigation to Poplar Bluffs, (*a*) to which even now some boats ascend in high water, and which is a shipping point of some importance for lumber. The Saint Louis, Iron Mountain and Southern railway follows the general course of the river, seldom more than a few miles distant from it, and much of the way skirting it closely; with this exception, the Black River basin has no railroad facilities. The country is rather sparsely settled and contains no large towns; Pocahontas, Corning, and Poplar Bluff are the most important places on the river, but the latter of these, which is the most populous, has only about 800 inhabitants.

Elevations on the Black river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Mill Spring*	418	101	†34	2.97
Near Poplar Bluff‡	317	122	‖311	0.39
Mouth of river§	195			

* Low water by levels of Saint Louis, Iron Mountain and Southern railway.
† Map measurement.
‡ Low water at crossing of Saint Louis, Iron Mountain and Southern railway.
§ Estimated from elevation at Saint Louis, Iron Mountain and Southern railway crossing below.
‖ From government engineers' report.

At Poplar Bluff, and for some distance above, the average width of the river is about 150 feet; the banks are rather low, and succeeded by bottom-land. Farther up stream, however, the banks are higher, the bed is gravelly, and there is a swift current, with numerous shoals. The Black, Little Black, Current, Eleven Point, and Spring rivers are said to have a general similarity. They are used only to a very small extent for power, but there are a considerable number of mills, in the aggregate, on their various minor tributaries; they are mostly flouring- and grist-mills of small size. These streams are clear and swift running, with gravelly beds in their middle courses and considerable rock in the upper waters. They are largely fed by springs, are steady in flow, and would furnish powers of good size. Some of the springs in this portion of Missouri are of sufficient volume to immediately supply power to small mills. At Mill Spring, in Wayne county, a mill is run in this way by water from a large spring which gushes out from the base of a bluff only a few hundred feet away. There is said to be another mammoth spring at the source of Spring creek.

Aside from the poor railroad facilities, the main objection to the larger tributaries of the Black and, indeed, to that stream itself, for power, lies in their being visited by heavy freshets, during which they overflow the bottoms extensively, and inflict much damage upon the farming lands by washing out the soil. The overflows are not so serious in the upper waters as below, and it is those portions which are, therefore, most favorable to use. At Mill Spring, on Black river, the range of the latter between extreme high and low water is 19 feet; near Poplar Bluff it is 22 feet, and near the mouth 31 or 32 feet.

Estimated volume and horse-power of Black and Current rivers.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
BLACK RIVER.	*Sq. miles.*						
Mill Spring	1,003	150	170	180	204	240	273
Poplar Bluff	1,315	190	216	230	261	320	364
CURRENT RIVER.							
Above Jack's Fork	784	110	125	140	159	190	216
Van Buren	1,739	250	284	310	352	420	477
Doniphan	2,388	350	398	420	477	580	659

NOTE.—Drainage area of Current at mouth, 2,935 square miles; Eleven Point, above junction with Spring, 992 square miles; Spring river at Canton, 1,034, and below Eleven Point, 2,333, square miles; Strawberry, at mouth, 740 square miles.

a Major W. H. H. Benyaurd, corps of engineers, estimates the expense of improving the stream from Poplar Bluff to the mouth at $80,000; $15,000 was appropriated by Congress in 1880. (See *Report Chief of Engineers*, 1880.)

Power utilized on the White river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
White	Arkansas	Arkansas	Benton	Flour, grist, and saw	1	14	30
Do	do	do	Washington	Saw	1	8	12
Black	White	Missouri	Wayne	Flour and grist	1	15	18
Do	do	do	Reynolds	do	1	4½	10
Strawberry	Black	Arkansas	Lawrence	Cotton-gin	1	5	20
Do	do	do	Sharp	Flour and grist	1	8	15
Do	do	do	Izard	do	1	6	16
Small streams	Strawberry	do	Lawrence	do	1	7	7
Do	do	do	Sharp	do	6	45	93
Do	do	do	do	Saw	3	22½	39
Do	do	do	do	Cotton-gin	1	7	10
Spring	Black	do	Fulton	Woolen	1	6	6
Do	do	do	do	Flour and grist	1	6	30
Do	do	do	do	do	2	16	35
Small streams	Spring	do	Randolph	do	3	12	36
Do	do	Missouri	Oregon	do	2	17	40
Do	do	do	do	Flour, grist, and saw	1	7	24
Current	Black	do	Ripley	do	1	5	25
Do	do	do	do	Flour and grist	1	.....	20
Do	do	do	Shannon	Saw	1	9	6
Small streams	Current	do	Ripley	Flour and grist	2	10	21
Do	do	do	do	Flour, grist, and saw	1	6	14
Do	do	do	Shannon	Flour and grist	3	27½	36
Do	do	do	Texas	do	2	11	14
Do	do	do	Dent	do	2	12	17
Do	do	do	do	Flour, grist, and saw	1	9	55
Do	do	do	Butler	Flour and grist	1	7	16
Do	Black	Arkansas	Independence	do	1	8	20
Do	do	do	Randolph	Woolen	1	4	.....
Do	do	Missouri	Butler	Flour and grist	1	7	12
Do	do	do	Reynolds	do	2	18	48
Do	do	do	do	Saw	2	24	62
Do	do	do	Iron	Flour and grist	1	6	18
Big North Fork	White	do	Douglas	do	2	26	16
Do	do	do	do	Saw	1	.....	20
Sundry streams	Big North Fork	do	do	do	1	5	10
Do	do	do	do	Flour, grist, and saw	1	6	32
Do	do	do	do	Flour and grist	5	35	48
James Fork	White	do	Christian	do	1	6½	12
Sundry streams	James Fork	do	Stone	do	6	67	160
Do	do	do	Barry	do	3	18	28
Do	do	do	do	Saw	1	9	20
Do	do	do	Christian	Flour and grist	2	13	46
Do	do	do	do	Woolen	1	6	4
Kings	White	Arkansas	Carroll	Flour and grist	1	8	6
Do	do	do	Madison	do	1	10	20
Small streams	Kings (?)	do	Carroll	do	3	26	34
Do	do	do	do	Cotton-gin	1	7	8
Do	White	do	White	Flour and grist	4	35	52
Do	do	do	Van Buren	do	2	.....	40
Do	do	do	do	Saw	1	24	15
Do	do	do	Independence	Woolen	1	10	8
Do	do	do	do	Flour and grist	8	54½	170
Do	do	do	do	Saw	1	8	25
Do	do	do	do	Saw and cotton-gin	1	10	50
Do	do	do	Izard	Flour and grist	1	7	16
Do	do	do	Baxter	do	2	17	25
Do	do	do	Marion	do	2	8	40
Do	do	do	Boone	do	3	18	26
Do	do	do	Newton	do	4	76	47
Do	do	do	do	Woolen	1	.....	5
Do	do	Missouri	Ozark	Saw	1	9	10
Do	do	do	do	Flour and grist	1	6	10
Do	do	do	Douglas	do	1	7	40
Do	do	do	Taney	do	4	24½	112
Do	do	do	do	Flour, grist, and saw	1	10	28
Do	do	do	Christian	Flour and grist	1	.....	7
Do	do	do	Barry	do	2	22	56
					411		

Power utilized on the White river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Small streams	White	Missouri	Barry	Woolen	1	16	24
Do	do	Arkansas	Benton	Flour and grist	1	31	8
Do	do	do	do	Saw	1	10	7
Do	do	do	Madison	Flour and grist	3		52
Do	do	do	Washington	Woolen	1	16	4
Total					130	1,031	2,146

THE CANADIAN RIVER.

This river, the largest tributary, in point of area drained, of the Arkansas, is formed by small streams rising on the eastern slopes of the Rocky mountains, near the boundary between Colorado and New Mexico. From the source of Vermejo creek, in San Francisco pass, it runs for about 140 miles in a direction somewhat east of south; it then turns and pursues a winding easterly course across the northwestern portion of Texas and a great part of the Indian territory, in which latter it unites with the Arkansas, some 70 miles by river above Fort Smith. It has a length, by general course, of between 700 and 800 miles, and a drainage area of a little more than 46,000 square miles. The population of this entire area is but about 22,500, (*a*) and it is only reached by railroads at the extreme headwaters and near the mouth.

The following description is that given by Major Long, who explored the river in 1820, and is taken from Humphreys and Abbot's report:

> This river has a broad valley, bounded by bluffs from 200 to 500 feet high, faced with rocky precipices near its source, and presenting abrupt declivities, intersected by numerous ravines lower down. It has a spacious bed, depressed but a few feet below the bottoms, and exhibiting one continued stratum of sand through the greater part of its length. It is the channel through which the water of a vast extent of country is carried off; yet, during most of the summer season it is entirely destitute of running water throughout a large proportion of its extent—a circumstance in proof of the aridity of the region drained by it. Fifty miles above its mouth, it receives at least two-thirds of its water from its principal tributary, denominated the North Fork. This fork rises between the Arkansas and Canadian, and has a meandering course of about 700 miles. Six miles above the fork just mentioned another tributary enters the Canadian, called the South Fork, about half as large as the other. Notwithstanding the supplies afforded by these two tributaries, the Canadian has not a sufficiency of water in summer to render it navigable even to their mouths.

Major Long further describes the river as bordered by fertile bottoms near its mouth, its valley containing an abundance of timber for 200 miles above. Passing still farther westward, however, the soil becomes sandy, even in the bottoms, vegetation is scant, and the waters of the river are brackish from the presence of common salt and sulphate of magnesia.

Drainage areas of the Canadian river and tributaries.

Stream.	Drainage area.	Stream.	Drainage area.
	Sq. miles.		*Sq. miles.*
Vermejo creek	594	Little river	942
Cimarron river	1,096	South Fork	824
Mora river	1,725	North Fork	15,122
Rio Conchas river	1,193	Canadian, at Fort Butler, below Arroyo de la Cinta	8,482
Ute creek	1,679	Canadian, below Deer creek	26,219
Deer creek	312	Canadian, at mouth	46,221

THE NEOSHO RIVER. (*b*)

Rising in Morris county, in eastern Kansas, the Neosho takes a southeasterly and then southerly course, and entering the Indian territory joins the Arkansas at Fort Gibson. It is 260 miles long by general course, and has a drainage area of 12,746 square miles, comprising portions of Kansas, Missouri, the Indian territory, and a small part of northwestern Arkansas. The surface is mainly prairie, and is exceedingly rich farming land, especially in the bottoms; the principal productions are wheat, corn, and oats. The river is quite thickly fringed with timber, which forms a belt 1 mile to 5 miles in width, narrowing in the upper course; the more common varieties of trees are black walnut, cottonwood, sycamore, hickory, pecan, burr-oak, black oak, and soft maple. The timber is said to be

a Statistics by Mr. Gannett in *Census Bulletin* No. 78. *b* Also called Grand river.

found most plentifully on the east side of the stream and this is claimed to be a common feature with the rivers of that section, and is explained by the prevailing westerly and southwesterly winds having driven the prairie fires toward the windward bank, while the leeward bank has been protected by the water. Where cultivation has put an end to prairie fires the timber spreads out on both sides into the prairie. A good quality of bituminous coal exists in southeastern Kansas, and is found along the Neosho. Building-stone is abundant and valuable, and includes sandstone, blue limestone, common limestone, and in the upper valley a beautiful white magnesian limestone, so soft when quarried that it can easily be sawed, chiseled, or planed, but which becomes hard on exposure. Rich deposits of lead and zinc are also found in the section drained by Spring river, in southwestern Missouri.

The Missouri, Kansas and Texas railway follows the general course of the river throughout its length, and it is also reached by various other lines. The valley is well settled, and the more important towns on the river, advancing up stream, are Chetopa, population, in round numbers, 1,300; Oswego, 2,400; Osage Mission, 1,300; Chanute, 900; Humboldt, 1,500; Iola, 1,100; Burlington, 2,000; Emporia, 4,600, and Council Grove, 1,000.

Elevations and slope of the Neosho river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Emporia†	1,161			
		105	40	2.63
Burlington†	1,056			
		102	41	2.49
Humboldt†	954			
		40	76	0.53
Oswego†	914			
		414	152	2.72
Mouth of river‡	500			

* Map measurement.
† Level of rails, Missouri, Kansas and Texas railway.
‡ Water surface, estimated from elevation of Arkansas river at Missouri, Kansas and Texas railway crossing.

The Neosho is quite a crooked river, and meanders back and forth through bottom-land, which ranges from 1 mile to 5 miles in width, and which rises by successive terraces to bluffs of moderate height. The banks are usually of soil, and are firm; now and then loose slate and soapstone are exposed where the river approaches the bluffs. The height of the banks is seldom less than 10 feet, and varies from that to 75 feet where bluffy. The bed in the vicinity of Oswego is a shale, not very firm. The river is there 200 feet wide, and 2 to 6 feet deep, in an ordinary stage; it has a swift current, and is a succession of pools and shoals of moderate slope. It is generally frozen over from January to March; sometimes the ice is no more than half an inch thick, but in the severe winter of 1880–'81 it formed to the depth of 10 inches.

Unexpected rises may occur at any time, but the annual high water is in May and June, and results from the heavy rains of that period. The stream rises rapidly, often 2 feet or more in a day, and is also quick to subside, having been known to fall 8 feet in a day at Oswego; the greatest recorded rise at that point is 22 feet. The banks have been overflowed extensively only twice in ten years. During high water the river sets up over the dams so as to hide them entirely from view; large amounts of drift are brought down, though not so much, it is said, as formerly; it passes over the dams without injuring them. An old resident of Neodesha, who formerly lived for some years by the Neosho, informed me that in 1860 the stream ran dry for six months, and that it was again dry in 1862 and 1864. There have been no such occurrences in recent years, and it is not probable that any will be noted again, for the country is now broken up by cultivation, the soil rendered receptive of water, and the streams are thereby made more steady.

There are flouring-mills on the Neosho at intervals all along its course above Oswego. They are reported to carry from two to six runs of stone each, and to have an abundance of water at all seasons. At Oswego there is a crib-work dam, filled with stone, 200 feet long and 7 feet high; it rests upon a rock foundation and has crib-work abutments. The race is about 450 feet long, 20 feet wide, and is built out into the stream, from which it is separated by a crib-wall; it fills up with loose shale and soapstone, and has to be cleaned out every year. With a new dam 10 feet head might be created at this privilege, but with the present structure only 6 feet is in use. About 60 horse-power is employed at Howell & Hall's flouring-mill.

In its upper course the Neosho receives from the west Cottonwood river, which runs easterly through Marion, Chase, and Lyon counties. This is about 80 miles long by general course, and, as shown by railroad levels, falls in the neighborhood of 170 feet between Florence and the mouth. It is about 120 feet wide near the latter, and is used for power at various points along its course by flouring-mills. The flow is quite uniform, but the mills are liable to be short of water in August and September.

Spring river, which drains several counties in southwestern Missouri, joins the Neosho from the east in the Indian territory, and is an important mill stream.

Drainage areas of tributaries of the Neosho river.

Stream.	Drainage area.	Stream.	Drainage area.
	Sq. miles.		*Sq. miles.*
Cottonwood, at Florence	598	Spring river, at mouth	2,669
Cottonwood, at Cottonwood Falls	1,356	Elk river	874
Cottonwood, at mouth	1,934	Cabin creek	609
Spring river, at Carthage	472	Spavina creek	291
Spring river, at Georgia City	1,191	Pryor creek	299
Spring river, at Empire City	1,915	Spring creek	291

Estimated volume and horse-power of the Neosho river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Below Cottonwood	2,726	60	68	110	125	180	204
Le Roy	3,212	70	80	130	148	220	250
Humboldt	4,121	110	125	160	182	280	318
Osage Mission	4,639	130	148	180	204	310	352
Oswego	5,228	150	170	200	227	350	398

NOTE.—Average rainfall on the section considered about 10½ inches in spring, 14 in summer, 8 in autumn, 5½ in winter, and 38 for the year.

Power utilized on the Neosho river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Neosho	Arkansas	Kansas	Labette	Flour and grist	1	6	60
Do	do	do	Cherokee	Saw	1	4½	10
Do	do	do	Neosho	Flour and grist	2	14	72
Do	do	do	Allen	do	2	15	145
Do	do	do	do	Furniture	1		45
Do	do	do	Woodson	Woolen	1	7½	18
Do	do	do	do	Flour, grist, and saw	1	8	58
Do	do	do	Coffey	Flour and grist	1	14	130
Do	do	do	do	Flour, grist, and saw	1	8	60
Do	do	do	Lyon	do	2	13	116
Do	do	do	do	Flour and grist	1	8	35
Do	do	do	Morris	do	1	8	75
Spring	Neosho	do	Cherokee	do	4	26½	140
Do	do	Missouri	Jasper	do	6	42	352
Do	do	do	do	Flour, grist, and saw	1	7	37
Do	do	do	do	Saw	2	13	80
Do	do	do	Lawrence	Woolen	1	8	13
Do	do	do	do	Flour and grist	3	28	62
Sundry small streams	Spring	do	Jasper	do	3	24½	100
Do	do	do	do	Saw	1	11	20
Do	do	do	do	Flour, grist, and saw	1	6	40
Do	do	do	Lawrence	Flour and grist	1	9½	5
Do	do	do	Newton	do	8	66	228
Do	do	do	do	Flour, grist, and saw	1	8	70
Do	do	do	do	Woolen	1		8
Do	do	do	Barry	do	1	10	10
Do	do	do	do	Flour and grist	3	48	64
Do	do	do	McDonald	do	2	16	57
Do	do	do	do	Flour, grist, and saw	2	16	167
Cottonwood	Neosho	Kansas	Lyon	do	1	7	73
Do	do	do	do	Flour and grist	1		
Do	do	do	do	Saw	1	9	120
Do	do	do	do	Furniture	1		
Do	do	do	do	Saw	1	5	8
Do	do	do	do	Flour and grist	1	7½	30

Power utilized on the Neosho river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Cottonwood	Neosho	Kansas	Chase	Flour and grist	3	22½	170
Do	do	do	Marion	do	2	19½	99
Small streams	Cottonwood	do	do	do	1	14	28
Do	Neosho	do	Labette	do	1	4½	16
SUMMARY.							
Neosho	Arkansas				15	106	824
Small streams	Neosho				1	4½	16
Spring	do				17	124½	684
Small streams	Spring				24	215	769
Cottonwood	Neosho				11	70½	500
Small streams	Cottonwood				1	14	28
Total					69	534½	2,821

THE VERDIGRIS RIVER.

This stream heads in the southeastern part of Chase county, Kansas, and, following a southerly course into the Indian territory, empties into the Arkansas only a mile or so above the Neosho. It is 190 miles long by general course, and drains an area of 8,010 square miles. Its principal tributaries come from the west, and are as follows: Bird creek, draining 1,228 square miles; Caney river, 2,221 square miles; Elk river, 677 square miles, and Fall river, 848 square miles. The Verdigris basin, in Kansas, at least, is good farming land, but the crops are said to suffer from extremes of rainfall, which is excessive in some years and very deficient in others. The railroad lines cross the river at considerable angles, and do not, therefore, give as good facilities along the immediate course as the Neosho enjoys. The more important towns on the river are Independence, 2,914 inhabitants, and Neodesha, with 924.

The Verdigris is about 120 feet wide at Neodesha in an ordinary stage. This stream and Fall river are said to be similar in character, and are used for power to about the same extent, there being several flouring- and grist-mills on each. They are subject to great fluctuations in volume. In fall, or late summer, they run very low for two months, the lowest stage usually being reached about the first of October. High water occurs from May to July, with a maximum in the middle or latter part of June. The freshet rise is extreme, and is even stated to have been 40 feet in one instance. Both rivers have generally rocky beds, composed of limestone and soapstone, and are inclosed by banks rising 20 to 40 feet above low water. These are occasionally overflowed, and have been so three times since 1869. Fall river is possibly even more unreliable than the main stream, and in about every alternate year runs extremely low. In 1868 it ran dry for two or three weeks. In 20 miles by straight course, or perhaps 40 miles by river, it is said to fall 100 feet.

The earlier dams on the streams in this section are described as having been generally constructed of brush and logs. They answered well enough in a full stage of water, but admitted a serious waste in low water. The present dams are of various types—brush, framed, or stone, usually. They frequently meet with injury, where not properly constructed, most often from the water washing around their ends. The mills are reported to be troubled in many cases by flooding, not having been located sufficiently high above the water.

Estimated volume and horse-power of Verdigris and Fall rivers.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
VERDIGRIS RIVER.	*Sq. miles.*						
Middletown	765	10	11	20	23	50	57
Below Fall river	2,063	30	34	60	68	130	148
Independence	2,839	50	57	80	91	180	204
FALL RIVER.							
Charleston	538	5	6	15	17	30	34
Mouth of river	848	10	11	25	28	50	57

NOTE.—Approximate rainfall on the section considered 10 inches in spring, 14 in summer, 7 in autumn, 5½ in winter, and 36½ for the year.

Power utilized on the Verdigris river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Verdigris	Arkansas	Kansas	Montgomery	Flour and grist	6	41	188
Do	do	do	Wilson	do	1	8	20
Fall	Verdigris	do	do	do	4	32	131
Do	do	do	Greenwood	do	3	34½	67
Sundry streams	do	do	Montgomery	do	1	7	18
Do	do	do	Chautauqua	do	4	31	48
Do	do	do	do	Flour, grist, and saw	1		30
Do	do	do	do	Saw	1	6	15
Do	do	do	Elk	Flour and grist	5	59½	122
Total					26	219	639

SUNDRY TRIBUTARIES OF THE ARKANSAS RIVER.

Illinois river joins the Arkansas from the northeast, just above the mouth of the Canadian; its basin comprises 1,470 square miles. The stream heads in the northwestern corner of Arkansas, in Benton and Washington counties, where its upper waters supply power to a number of small mills. It is described as a fine stream, fed from the mountains, clear and constant in flow, and averaging near the mouth at least 100 square feet in cross-section, with a current of 3 miles an hour.

Walnut creek runs southerly through Butler and Cowley counties, in southern Kansas, and joins the Arkansas at Arkansas City. It is about 75 miles long by straight course, and drains 2,005 square miles. There are several flouring- and grist-mills on the stream, the lowest of which, located at Arkansas City, has a fine and expensive stone dam. The mill carries five runs of stone, and obtains sufficient water for about five months in the year to run at full capacity, but uses steam as auxiliary power the remainder of the time; the head on the wheels is 8 feet. At Winfield there are two mills, one supplied through a tunnel about 75 feet long, which has been run across the neck of a bend; 65 horse-power is used, with a head of 8½ feet. There is a fall of about 57 feet between Winfield and the mouth, or say 2.5 feet per mile. In some years the creek furnishes sufficient water throughout to the lower mills, while in other years the supply is entirely below their needs. The Walnut is claimed to be a better stream for power than the prairie creeks emptying into the Arkansas farther west, so it may be judged that those have very little value.

The Little Arkansas river empties from the north at Wichita. It answers for small powers, and is used by a few mills, but the bed is sandy and unfavorable for dams. There was formerly a flouring-mill on the stream at Wichita; it was subsequently burned, but was being rebuilt at the time of my visit. The Little Arkansas drains 1,287 square miles.

Summary of power utilized on the Arkansas river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Arkansas	Mississippi	Kansas	Reno	Flour and grist	2	10	125
Do	do	Colorado	Pueblo	do	1	14	40
Do	do	do	Fremont	do	1	12	60
White and tributaries	Arkansas	Arkansas and Missouri.		(See description)	130	1,031	2,146
Sundry streams	do	Arkansas	Van Buren	Saw	1	10	8
Do	do	do	Conway	do	1	9	25
Do	do	do	Yell	Flour and grist	1	13	20
Do	do	do	Pope	do	2	8	28
Do	do	do	Johnson	do	5	39	52
Do	do	do	do	Woolen	1		8
Illinois and tributaries	do	do	Benton	Saw	1	14	20
Do	do	do	do	Flour and grist	5	82	96
Do	do	do	Washington	do	7	119	113
Neosho and tributaries	do	Kansas		(See description)	69	534½	2,821
Verdigris and tributaries	do	do		do	26	219	639
Walnut and tributaries	do	do	Cowley	Flour and grist	3	22	132
Do	do	do	Butler	do	6	51	160
Little Arkansas	do	do	Harvey	do	3	29	80
Sundry streams	do	do	Barbour	Saw	1	41	42
Do	do	do	Sumner	Flour and grist	2	17	30
					416		

Summary of power utilized on the Arkansas river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Sundry streams	Arkansas	Kansas	Kingman	Flour and grist	1	15	40
Do	do	do	Pratt	do	1	20	20
Do	do	do	Sedgwick	do	4	30	61
Do	do	do	Reno	do	1	18	75
Do	do	do	Pawnee	do	1	13	20
Do	do	Colorado	Las Animas	do	3	42	35
Do	do	do	Huerfano	do	3	85	65
Do	do	do	do	Saw	1	34	20
Do	do	do	El Paso	Plaster	1	26	25
Do	do	do	do	Flour and grist	1	12	20
Do	do	do	Custer	Saw	1	14	20
Do	do	do	Chaffee	do	2	25	50
Total, Arkansas and all tributaries.					288	2,608½	7,096

X—THE RED RIVER BASIN.

THE RED RIVER.

PHYSICAL FEATURES OF THE COUNTRY, AND DESCRIPTION OF THE MAIN RIVER.

Red river is the most southerly of those great streams which drain the prairie regions east of the Rocky mountains, and then find their way into the Mississippi and the Missouri. In much of its course it is similar to the Arkansas, Kansas, and Platte. It rises in the northwestern part of Texas, a little south of latitude 35°, and about 30 miles east of the boundary between Texas and New Mexico. After running easterly about 200 miles, by general course, it is joined by the North Fork, after which the main river receives numerous accessions, mostly from the north. It forms the southern boundary of the Indian territory, and for a short distance also divides Texas and Arkansas; but soon after entering the latter state its course changes to the south, and it passes into Louisiana. It flows in a southeasterly direction across that state, and empties into the Mississippi 116 miles, by river, above the mouth. It extends through eleven degrees of longitude, and has a length, measured along its general course, of about 810 miles; it is a very crooked stream, however, and its actual length is probably as great as twice the above distance.

The water-shed lines of this river cannot be laid down with accuracy, but inclose an area which I estimate at about 92,700 square miles. Of this area there is contained in Texas, 31,800 square miles; in Indian territory, 25,300 square miles; in Arkansas, 18,600 square miles; in Louisiana, 17,000 square miles. The extent of area drained above various points is as follows:

Drainage areas of the Red river.

Locality.	Square miles.	Locality.	Square miles.
Above North Fork	12,400	Above Little river	68,200
Below North Fork	17,200	Below Little river	71,300
Above Washita river (Indian territory)	32,200	Above Black river	71,500
Below Washita river	40,300	Below Black river	92,500
At Shreveport	61,400	At mouth	92,700

The basin of the river presents great variety in natural features. That portion about its source constitutes a part of the desolate plateau known as the Llano Estacado, with an elevation of 2,500 feet above sea-level. Eastward, as far as the Cross Timbers, between the meridians of 97° and 98°, the country continues barren and unproductive. Beyond that limit, however, it is fertile, well timbered, and covered with vegetation. In Arkansas, around the upper waters of the Ouachita, are low mountains; farther south these subside into hills, and as we approach the main river in Louisiana the country becomes comparatively level, and contains a great many bayous and swamps. All this portion of the Red River basin is heavily timbered, yellow pine, various kinds of oak, and cypress being the principal varieties, besides which there are large amounts of black walnut, maple, beech, sycamore,

hickory, and ash. The soil, and especially the alluvial soil of the river bottoms, is extremely fertile. Cotton is the great staple of production, but corn, wheat, oats, potatoes, tobacco, and hay are also largely raised. A greal deal of stock is also shipped from this section to New Orleans. The mineral resources are small, though magnetic iron ore occurs near the sources of the Ouachita.

The climate of the Red River basin is mild, and on the higher and cleared ground is very healthy. Along the river bottoms, with their numerous swamps and luxuriant vegetation, there is the same frequency of chills and fever as in similar regions elsewhere. The average temperature at different points is given as recorded by the Smithsonian Institution:

Temperature of the Red River basin.

Locality.	Years of observation.	Spring.	Summer.	Autumn.	Winter.	Year.
		°	°	°	°	°
Rapides, Rapides parish, Louisiana	10	67.50	80.10	66.53	53.12	66.81
Monroe, Ouachita parish, Louisiana	10	71.53	80.95	59.30	43.87	63.91
Washington, Hempstead county, Arkansas	22	62.26	78.19	61.20	44.61	61.56
Fort Towson, Indian territory	18	62.23	78.92	61.09	43.74	61.50
Fort Arbuckle, Indian territory	12	61.54	80.22	61.67	40.76	61.05
For country thence to source (estimated)	.....	.....	78.50	.....	38.00	62.00

The means of communication in this region must be classed as poor. The Missouri, Kansas and Texas railway crosses the basin, striking the river in the vicinity of Denison, Texas, some 430 miles by general course above the mouth. Again, at Fulton, Arkansas, about 170 miles farther down the river, the Saint Louis, Iron Mountain and Southern line crosses. From Shreveport, still farther down, the Texas and Pacific railway runs westerly, but with the exception of one or two short spurs which touch the outskirts of the basin on the east, there are no other lines of importance. The water routes are very valuable, though they might be much improved. Navigation of Red river extends to Shreveport, 460 miles by water from the mouth, throughout the year, and in high water boats have ascended far above, into the Indian territory. This upper section has very little depth of water at a low stage, contains many obstructions, and above the mouth of Bois d'Arc creek is not considered to have any possible value for navigation. Although steamers of 4 feet draught can reach Shreveport, except in extremely low water, navigation below that point is subject to many dangers and hindrances, owing to its obstruction by snags, leaning timber, and accumulations of logs in the form of rafts. Work has been carried on for many years past, and is still prosecuted, by the general government, to the end of removing existing obstructions, and, so far as possible, preventing the formation of new ones. The most famous of these operations have been in connection with the removal of the great "Red River raft", which was last cut through in 1873 by Lieutenant E. A. Woodruff, of the corps of engineers. Navigation is also carried on up the Black and Ouachita, and some of their tributaries, except in low water.

In the decade previous to 1880 the population of the Red River basin increased nearly 60 per cent., or from 456,000 to 728,000. It is mainly confined to Louisiana and Arkansas, is very much scattered, and is composed chiefly of farmers and planters.

To come more directly to the river itself, as described in Humphreys and Abbot's report it has its source in the eastern rim of the Llano Estacado. Through the Llano its course is in a deep and rugged ravine, shut in by almost vertical sandstone cliffs, rising above it 500 to 800 feet. It here flows over a gypsum formation, which renders its waters nauseating and unwholesome. About 8 miles below the point where it leaves the Llano the river is described as "900 yards wide, flowing over a very sandy bed, with but little water in the channel, and fortified upon each side by rugged hills and deep gullies. * * * The soil throughout this section is a light ferruginous clay, with no timber except a few hackberry and cottonwood trees upon the banks of the streams." Captain Marcy, from whose account the above is quoted, continues: "There is but little water either in the river or in the creeks, and in a dry season I doubt if there would be any found here." The North Fork enters the river on the western border of the Wichita mountains. These consist of detached peaks of a conical shape, evidently of volcanic origin, and present a grand but desolate appearance. Immediately surrounding these mountains the country is fertile and timbered. Between longitudes 97° and 98° the "Cross Timbers" are met with. They are a remarkable strip of timber, 5 to 30 miles in width, extending some 400 miles in a southwesterly direction, from the Arkansas to the Brazos. East of this point the country along Red river is well timbered and very productive. The river itself also changes in character. Previously it has been a wide stream, 2,000 to 3,000 feet across, flowing with quite rapid descent over a sandy bed, and of shallow depth—not more than 6 or 8 feet, even in floods. It now winds through an alluvial bottom, has a muddy bed, a slight fall, is only 600 to 800 feet wide, even as far down as the mouth of Black river, and is subject to oscillations of 40 feet or more. Its character remains substantially the same through the remainder of its course. In what is known as the "raft region", in northwestern Louisiana, it is bordered by numerous extensive lakes and swamps. For the past fifty years there has been a gradual filling up of its mouth, and the consequent throwing of its waters into what is supposed by some to have been its ancient and exclusive channel—the Atchafalaya river.

The elevations and slope of the river are shown in the accompanying table:

Elevations on Red river.

Locality.	Feet above tide.	Intervening distance in miles.*	Average slope in feet per mile.
Source †	2,450.0	504	3.81
Missouri, Kansas and Texas railway crossing, north of Denison, Texas ‡	531.0		
Saint Louis, Iron Mountain and Southern railway crossing, at Fulton, Arkansas §	226.5	300	1.02
Same at high water	258.5	265	0.30
Shreveport, high water †	180.0		
Mouth Black river, high water ‖	54.0	460	0.28
Mouth Red river, high water ¶	49.5		
Mouth Red river, low water **	13.7	.....	.....

* Of the intervening distances given, the first in order is by careful measurement on Colton's map of Texas; the second is as given in Major W. H. H. Benyaurd's report of a reconnaissance (see 1879 *Report Chief of Engineers*); the third appears from Humphreys and Abbot's report, and the fourth, from Shreveport to the mouth, is from Major Benyaurd's report dated July 1, 1878.

† Elevation as given by Humphreys and Abbot.

‡ Low water, by Missouri, Kansas and Texas railway levels.

§ Low water, by Saint Louis, Iron Mountain and Southern railway levels.

‖ See report Board of Engineers in *Report Chief of Engineers* 1880, page 1285.

¶ See above report Board of Engineers.

** Levels of precision under Coast and Geodetic Survey.

Value for power.—As to the actual availability for water-power of the Red river and its tributaries I can say nothing from personal observation. The streams were too inaccessible and plainly of too little value to warrant spending the time necessary to reach them. By the kindness, however, of Major C. W. Howell, of the corps of engineers, I gained, through his assistants, valuable information of a general character regarding these rivers. Red river itself is said to have no practical value for power, even at a distance of 400 miles west of Denison. This might, indeed, be inferred easily enough from the description previously given. Except, perhaps, toward the extreme source, the river is without abrupt falls, but descends evenly and with no very rapid slope. In the upper section the bed is wide and sandy, and in a low stage contains little or no running water. The tributaries which it receives in that part of its course from the prairies run dry, or nearly so, in summer, and after heavy rains the small streams are subject to sudden and great floods.

The employment of the lower main river for power is evidently out of the question. At what are known as the "Falls of Alexandria" the river descends a few feet, (*a*) but the falls are of no account for water-power, and are visited with a freshet rise of 35 to 40 feet.

The prevailing winds in the Red River basin are southerly, bringing moisture from the Gulf, and resulting in abundant rainfall over that portion which lies at all north of the Gulf. The amount of this precipitation at various points is shown below:

Rainfall of the Red River basin.

Locality.	Years of record.	Spring.	Summer.	Autumn.	Winter.	Year.
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Fort Jesup, Sabine parish, Louisiana	10	13.38	10.94	9.79	11.49	45.60
Monroe, Ouachita parish, Louisiana	10	.....	.....	.....	.....	54.00
Washington, Hempstead county, Arkansas	22	15.64	12.42	12.12	14.07	54.25
Fort Towson, Indian territory	14	15.55	14.36	12.23	8.94	51.08
Fort Arbuckle, Indian territory	12	8.86	11.87	8.22	4.92	33.87
Above Fort Arbuckle (estimated)	.....	6.00	6.00	4.00	3.00	19.00

From these records it is seen that the upper basin has a feature common to the rest of the great prairie region west of the Mississippi and Missouri, namely, a much smaller rainfall in winter than in the other seasons. As we advance down the river its ratio rises, and for the lower half of the basin the rainfall both in winter and spring is greater than in summer and autumn. The evaporation being vastly greater in the latter period than in the former, while there is less rain, the result is to bring about great unevenness in the volume of the streams, so that while there is high water from midwinter on to early summer, there is a rapidly succeeding stage of low water, reaching its minimum in late summer or early fall. It is during the high water of winter and spring that navigation

a 3.5 feet in 6,000 feet.

is best in the main river, and many of its tributaries are not, in their present condition, navigable at all, except during those seasons. As to the actual volume of flow in Red river, the only data of importance which I have been able to find are shown below:

Volume of Red river.

Drainage area.	Volume, cubic feet per second.	Cubic feet per second per square mile.	Remarks.
Sq. miles.			
92,700	220,000	2.373	Discharge in the great flood of 1851, when standing at Alexandria 1.1 foot below the highest point attained in 1849. (See *Report of Board of Engineers*, p. 1286 of *Report of Chief of Engineers* for 1880.)
92,700	57,000	0.615	Mean discharge as given by Humphreys and Abbot. Ratio between drainage and rainfall stated as 0.20.
92,500	10,775	0.117	Gauging made by direction of Major Benyaurd, below the mouth of Black river, when Red river was near its low-water mark. (See p. 1295, *Report Chief of Engineers* for 1880.)

TRIBUTARIES OF THE RED RIVER.

The tributaries which Red river receives from the south in Louisiana have no importance for power; they consist of a net-work of sluggish streams and bayous, the latter serving as high-water channels. The Louisiana streams tributary to Red river from the north, with the exception of the Ouachita, have likewise no value. The country through which they flow is heavily timbered with pine, and toward the northern part of the state rises into hills 200 to 350 feet high. The whole district is very sparsely settled, so sparsely, indeed, and so poorly provided with means of communication, that there is even very little cutting of timber. The streams are bordered by rich alluvial bottom-lands, varying from a few hundred feet to three-quarters of a mile in width, and during freshets spread out for miles in width over these and the adjoining country. They are said to have quite a rapid fall, over gravelly beds, but the country drained by them is almost devoid of springs, and in summer the streams, having to depend upon surface drainage, go nearly dry. The only water-powers used are employed by a few scattering grist- and saw-mills, and perhaps occasionally a cotton-gin, but these powers are, for the most part, available only in high water. The names of the more important tributaries of the Red river, and their drainage areas, are given in the following table. The areas are only approximate, for the lower basin is so cut up by bayous that it is impossible to say just where the water-shed lines should run. Of these streams, Black river, which is formed by the Ouachita and Tensas, is navigable throughout. The Ouachita, its main tributary, will be separately described further on.

Tributaries of the Red river (in order from the source).

Name of stream.	Drainage area.
	Square miles.
Salt Fork	1,740
North Fork	4,800
Cache creek	2,000
Big Wichita river	2,940
Big Beaver creek	870
Little Wichita creek	1,390
Mud creek	630
Washita river (Indian territory)	8,100
Blue river	700
Boggy creek	2,760
Kimishi river	2,820
Little river (Indian territory and Arkansas)	3,050
Sulphur Fork	3,770
Cypress creek, at head of Ferry lake	1,960
Bayou Badeau, including Swan lake	1,020
Bayou Dauchitte, including lake Bistineau	1,310
Black Lake bayou, below mouth Saline bayou	1,390
Little river (of Louisiana)	3,100
Black river, including the Ouachita and Tensas	21,000

THE OUACHITA RIVER.

This is the most important stream tributary to Red river, as well as the greatest in extent of area drained. It rises in the Rich mountains, in the northwestern part of Polk county, Arkansas, only a few miles from the western boundary of that state. It runs easterly through Polk and Montgomery counties, after which its general direction becomes southeasterly, and remains so through Arkansas. It enters Louisiana about 50 miles west of the

Mississippi river, as the boundary between Union and Morehouse parishes, and, taking a more southerly course than before, unites with the Tensas on the eastern border of Catahoula parish, to form Black river. By using measurements given in the report of United States engineers, and by careful measurements of the remaining distance on the land-office maps, I find a length of 580 miles for this river, which is, doubtless, considerably under the truth. Its length, measured by general course, is 320 miles. It drains an area of about 19,000 square miles, the general surface features of which have been sufficiently described in connection with the Red river. Its basin comprises the greater part of southern Arkansas, and a large portion of northern Louisiana. Its extent above different points on the river is as follows:

Drainage areas of the Ouachita river.

Locality.	Square miles.	Locality.	Square miles.
Crystal Hill, Montgomery county, Arkansas	350	At Camden	5,600
Harold, Montgomery county	1,000	Above Bayou Moro	6,860
Malvern, Hot Springs county	1,630	Below Bayou Moro	7,430
Above Caddo creek	1,910	Above Saline river	7,540
Below Caddo creek	2,390	Below Saline river	10,970
Above Little Missouri river	2,840	At Monroe	16,050
Below Little Missouri river	5,030	Above junction with Tensas bayou	19,050

Arkadelphia, about 380 miles by water above the mouth of the river, is regarded as the head of steamboat navigation. It is so, however, only during high water, and in medium stages boats do not pass above Camden, some 300 miles from the mouth. In very dry seasons the river runs extremely low, and is practically not navigable. Major Benyaurd has reported, however, that by the improvement of Catahoula shoals, below Columbia, navigation could be assured to that point, say 70 miles from the mouth, throughout the year. The original design for improving the Ouachita contemplated a system of locks and dams, estimated to cost about $1,163,000, and some appropriations were made by the general government for carrying out the plan. It was soon abandoned, and since then work has been mainly confined to the removal of snags. From March 3, 1871, to June 14, 1880, $251,000 had been appropriated to this stream.

From Rockport to Arkadelphia the river is described by Mr. Justin Straszer, civil engineer, as running over a gravelly bed covered with bowlders. (*a*) Overhanging trees, snags, and sunken logs abound. The bottoms are heavily timbered, and in high water are overflowed 2 to 10 feet deep. Heavy rains in the mountains above sometimes cause sudden oscillations of 15 to 25 feet within half a day or a day in this portion of the river. The banks are 15 to 25 feet high, and are firm. "Where the high uplands strike the river the lowest strata of the bluffs expose rocky ledges, which crop out frequently and form at times part of the river bed."

From Arkadelphia to Camden the river averages about 460 feet in width between banks on the shoals. Toward the Louisiana line its average width between banks is about 600 feet. Through these sections the river is winding in its course, and runs through alluvial bottoms, heavily timbered and containing numerous cypress swamps. During high water these bottoms are, as a rule, extensively overflowed.

The elevations and slope of the Ouachita are shown in the accompanying table:

Elevations on the Ouachita river.

Locality.	Miles from mouth.	Feet above tide.	Average fall in feet per mile.
Extreme source *	581	(?) 2,000.00	
Arkadelphia, high water †	380	187.96	9.15
Arkadelphia, low water ‡	380	161.50	
Camden, high water ‡	304	§ 113.50	1.12
Camden, low water ‡	304	76.50	
Mouth Bayou Bartholomew ‖	148	93.00	0.19
Monroe ‖	122	88.00	
Harrisonburg, high water ¶	16	67.00	0.20

* Elevation given by Lieutenant Whipple (quoted by Humphreys and Abbot.)

† Level of water surface where crossed by Saint Louis, Iron Mountain and Southern railway, by profile of that road.

‡ Levels Saint Louis, Iron Mountain and Southern railway.

§ With reference to this elevation J. H. Morley, esq., chief engineer of the Saint Louis, Iron Mountain and Southern railway, wrote me as follows: "It is a curious fact that the Ouachita river at this point, among the hills, should be lower than the Mississippi at Arkansas City, due east therefrom, where high water is 145 feet above tide water, but well verified levels attest the fact."

‖ High water by railroad levels (quoted by Humphreys and Abbot).

¶ Humphreys and Abbot. Delta survey.

a Report Chief of Engineers, 1871.

The river being navigable to Arkadelphia, only that portion above can be considered with reference to water-power. Between Arkadelphia and Rockport the descent of the stream is small, probably not exceeding, on the average, 2 feet per mile. The extreme oscillations in this part of the river, (*a*) and the consequent flooding of the bottoms, render it very unfavorable to use for power. Between Malvern and Arkadelphia, the main line of the Saint Louis, Iron Mountain and Southern railroad follows the stream, giving very direct connections with Texas on the one hand, and with Little Rock and Saint Louis on the other. Nearly the whole of the section of river we are considering lies in Hot Springs county, which has a population of about 7,800; Malvern has about 1,200 (?) inhabitants, and Arkadelphia, which lies in Clarke county, about 1,500.

Above Rockport the river runs from the west, and its course lies among low mountain ranges, which hem it in pretty closely, but nowhere rise above it more than 300 to 600 feet. In the vicinity of Hot Springs the rock is largely slate; what is known as Whetstone mountain is mainly composed of novaculite rock, which is largely quarried and exported for manufacture into whetstones, honestones, and slabs for use in engraving. In this section there is also found a large deposit of magnetic iron ore lying immediately beneath the surface. Garland county has a population of about 9,000, of which 3,600 belongs to Hot Springs. On account of its springs the latter place has become a famous resort for people from all parts of the United States. It lies among low mountains in a narrow valley, through which runs a small stream, called Hot Spring creek, its waters at a summer temperature of 107°. It receives contributions, within the town, from more than fifty mineral springs, the waters of the different ones ranging in temperature from 100° to 148° Fahrenheit. Hot Springs lies about 6 miles north of the Ouachita, and is connected at Malvern with the main line of the Saint Louis, Iron Mountain and Southern railway by a branch 25 miles long. For half that distance the railroad lies less than 2 miles from the river, and occasionally approaches it closely.

Throughout the upper portion of its course the fall of this river is quite rapid; there are no abrupt descents, but successive riffles, with here and there a quiet stretch intervening. The stream is less than 200 feet in width between banks, and has a rocky bed much of the way, very favorable to dams. I was informed by the surveyor of Garland county that there are numerous good sites to be found, naturally well suited to the location of mills, and out of reach of high water. It is stated that at some points 18 feet fall is available within half a mile. The stream is utilized at only one or two points in its whole length. The more important of these is Thornton's mill, 8 miles from Hot Springs; a fall of 9 feet is employed, power being supplied to a small two-run grist-mill, a cotton-gin, and a saw-mill. The utter absence of all railroad facilities above Hot Springs would preclude, at present, any important use of the stream for power, even if there were no other obstacles. Probably the true reasons for the small employment of water-power in this section are the sparse population, almost entirely devoted to farming, their inaptitude for manufacturing pursuits, their distance from important markets, and their lack of capital. As described by Humphreys and Abbot, the Ouachita has its source in sterile, mountainous prairies; toward the headwaters of the Little Missouri, however, these disappear, the soil becomes more fertile, being adapted to potatoes and small grains, and timber abounds, including considerable tracts of pine and black oak. The extent to which cotton is raised in the Ouachita basin may be inferred from the report (*b*) of Major Benyaurd, corps of engineers, who states that during the fiscal year ending June 24, 1879, the amount of cotton shipped down the Ouachita from the country along the main stream and its tributaries, Saline river, Bayou Bartholomew, Bayou d'Arbonne, and Little river, reached 179,700 bales, with a value of $7,188,000. The basin of this river also yields largely in corn, wheat, and tobacco.

In the vicinity of Hot Springs the width of the Ouachita between banks ranges from 150 to 200 feet, but in very low water the stream scarcely covers its bed, and can easily be walked across in places. Its water-shed being rocky, with abrupt slopes, the river is subject to great oscillations; it rises rapidly after a heavy rain, sometimes coming up 10 or 15 feet in a single night. Humphreys and Abbot quote Darby as saying of this river:

> Few rivers differ more in the quantity of water at different seasons than the Ouachita. Flowing from a hilly or mountainous tract, more constancy might be expected in the column of water; but though the places drained by the Little Missouri and Fourche Caddo are not deficient in springs, yet the extensive region toward the sources of the Ouachita has little water except what is supplied by rains in winter and spring. When the parching heat of summer has dried the country above the mouth of the Little Missouri, the Ouachita becomes very low as far south as the head of Black river.

If we take the record kept at Washington, Hempstead county, as applicable to the upper basin of the Ouachita, its temperature is about as follows: Spring, 62°; summer, 78°; autumn, 61°; winter, 45°; year, 61.5°.

There are no long-continued records of rainfall in the upper Ouachita basin, but from the Smithsonian rain charts I estimate the precipitation as follows: Spring, 15 inches; summer, 12 inches; autumn, 11 inches; winter, 12 inches; total for year, 50 inches. While the temperature is considerably above freezing in winter, it is much lower than that which produces the great evaporation of summer; again, the rainfall during winter and spring is, in the aggregate, 4 inches more than in the remainder of the year. We thus, naturally, find high water prevailing during the former period, followed by decreasing stages during the summer and autumn. Mr. Straszer, in his report previously referred to, states that high water sets in about December 1, and a fair stage continues on through the spring freshets. Low water begins in June, the lowest stage being usually in August and September.

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a The range between extreme high and low water at Arkadelphia is 26½ feet.

b See *Report Chief of Engineers*, 1879.

Two gaugings have been made on the Ouachita, with the purpose of finding its low-water volume. I am informed by Major Benyaurd that, in a report to Colonel W. F. Raynolds, in 1872, Clement Smith, assistant engineer, stated that he had gauged the Ouachita at Monroe, when the river was some 10 or 12 inches above its lowest stage, and found the discharge about 800 cubic feet per second. He deduced that the low-water discharge at Monroe was about 600 cubic feet per second, and that at Camden the discharge could not be over 400 cubic feet per second.

In 1874, Mr. Durham, assistant engineer to Major Benyaurd, gauged the river at Camden, and gave the resulting low-water discharge at 353 cubic feet per second. The results of these various gaugings and estimates may be thus presented:

Gaugings and estimated volume of the Ouachita river.

Locality.	Drainage area.	Rainfall on tributary area.					Volume, cubic feet per second.	Cubic feet per second per square mile.	Remarks.
		Spring.	Summer.	Autumn.	Winter.	Year.			
	Sq. miles.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*			
Camden	5,600	15	12	11	12	50	353	0.063	Low water, as estimated by Mr. Durham, 1874.
Do	5,600	15	12	11	12	50	400	0.071	Low water, as estimated by Clement Smith, 1872.
Monroe	16,050	17	12	11	14	54	600	0.037	Low water, as estimated by Clement Smith.
Do	16,050	17	12	11	14	54	800	0.050	Gauging by Clement Smith; river 10 or 12 inches above low water.

The following table gives my estimate of the volume and corresponding horse-power at several points on the upper Ouachita. The estimate is for the constant flow of the river, independent of storage afforded by dams:

Estimated volume and horse-power, Upper Ouachita river.

Locality.	Drainage area.	Low-water, ordinarily dry year.		Low water, average year.		Available 10 months in average year.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Crystal Hill, Montgomery county	350	10	11	20	23	45	51
Harold, Montgomery county	1,000	50	57	80	91	170	193
Malvern, Hot Springs county	1,630	90	102	150	170	300	341
Below Caddo creek	2,390	150	170	220	250	440	500

The more important tributaries of the Ouachita, in order from the source, with their drainage areas, are as follows:

	Square miles.
Caddo creek	480
Little Missouri river	2,190
Smackovert creek	540
Bayou Moro	570
Saline river	3,430
Bayou Bartholomew	1,950
Bayou Loutre	440
Bayou D'Arbonne	1,910
Bayou Boeuf	2,190

I have very little detailed information regarding any of these streams. In their lower courses they would be found altogether too sluggish to be of value, and in their upper waters they have too little volume to carry any but small powers. There is an occasional small grist- or saw-mill to be found on their upper portions, or on some tributary; otherwise they are unused for power. The larger of the streams in the above list are navigable during high water for some little distance above their mouths, but without exception they are either very poorly or not at all provided with railroad facilities. The upper waters of the Saline and the lower course of the Little Missouri are crossed almost at right angles by the Saint Louis, Iron Mountain and Southern railway; Bayou Bartholomew and Bayou Boeuf are also crossed by short lines running to the Mississippi, but the other streams are not even touched by any railroad.

Little Missouri river rises in the southeastern part of Polk county, Arkansas. It flows southeasterly and joins the Ouachita 25 miles above Camden. In high stages it is navigable about 68 miles (by river) above its mouth, to Antoine creek. In this distance it averages about 300 feet in width between banks. Its course lies through alluvial

bottom-land, 4 to 6 miles in width, covered with heavy timber, canebrakes, and cypress swamps, and intersected with bayous. Some of the bottoms are above the reach of freshets, and are cultivated. As a rule, however, they are overflowed 3 to 10 feet deep during high water. A large part of the territory drained by this river is "black land", 100 to 200 feet thick, underlaid by the Cretaceous formation. It yields 1,800 pounds of cotton in seed, and 60 to 75 bushels of corn, per acre.

Saline river is formed by small forks rising in Saline and Garland counties, Arkansas, 18 to 20 miles north of Hot Springs, and 40 to 45 miles west of Little Rock.

Its course is southeasterly, and afterward southerly, joining the Ouachita on the eastern border of Union county, 10 miles north of the Louisiana line. Its drainage area is 3,430 square miles. This stream was examined and reported upon, in the winter of 1878–'79, by Mr. Zeph Harrison, civil engineer. (*a*) He states the length of the river to be about 485 miles. The Saint Louis, Iron Mountain and Southern railway crosses the stream at Benton, in its upper waters. For 225 miles below that crossing the river is tortuous and full of shoals, its bed and banks are gravelly, and its course is obstructed by many jams of timber and drift. The bottoms bordering the stream are very productive and yield good crops of cotton and grain. The valley of the stream and the ridges on either side are covered with a heavy growth of valuable timber—white oak, yellow pine, and a great many other varieties. The stream is not used for water-power, and does not appear to be favorable to such employment. In the lower river the fall is estimated at about 5 inches per mile. The Saline is said to be navigable 70 or 80 miles from its mouth in high water.

The character of the upper portion of Bayou Bartholomew may be sufficiently judged from the following description by Mr. M. L. Lum, civil engineer:

The principal source of the bayou is Bird's spring, situated among the pine hills in the westerly part of Jefferson county, and distant 16 miles northwest from Pine Bluff. Before reaching the Louisiana line the bayou flows through Jefferson, Lincoln, Drew, and Ashley counties, touching Desha and Chicot counties on the west, the general course being parallel with the Arkansas river, at distances from it varying from 15 to 30 miles. The current is very sluggish, there being very few places where the velocity is 2 miles per hour, and the course of the bayou exceedingly tortuous. In the vicinity of Pine Bluff the Arkansas river is distant only 4 miles from the bayou, and at its highest stage has been known to flood the intervening country, and here it is proposed by parties interested in the bayou to have a canal cut, thus relieving the Arkansas river, in a measure, at its highest stage, and increase the current in the bayou, thereby removing some of the obstructions and benefiting the health of the people along its banks.

For a distance of 20 miles below Pine Bluff, on the right bank of the bayou and adjacent to it, are found bluffs 50 feet in height, covered with pine and scrub-oak, with soil of a sandy nature, while on the opposite side it partakes of the character of the Arkansas River valley, the soil being in most places what is termed "buckshot", and the land being overflowed in high water for a distance of one-half mile back from the bayou, the overflow having an extensive growth of gum, cypress, water-oak, and hickory.

Power utilized in the Red River basin.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Ouachita	Red	Arkansas	Hot Springs	Cotton-gin	1	9	20
Do	do	do	Garland	Flour, grist, and saw	1	9	37
Do	do	do	do	Saw	1	20	25
Sundry streams	Ouachita and tributaries	do	Union	Flour and grist	3	25	24
Do	do	do	Ouachita	Saw	1	9	18
Do	do	do	Hempstead	do	1	6	24
Do	do	do	do	Flour and grist	2	15	23
Do	do	do	Dallas	do	3	20	37
Do	do	do	do	Saw	1	6	20
Do	do	do	Grant	Cotton-gin	1	8	30
Do	do	do	Saline	Saw	1	8	22
Do	do	do	do	Flour and grist	1	9	15
Do	do	do	Pike	do	3	35	102
Do	do	do	do	Flour, grist, and saw	1	15	25
Do	do	do	do	Cotton	1	10	48
Do	do	do	Hot Springs	Cotton-gin	2	15	33
Do	do	do	do	Saw	1	18	30
Do	do	do	do	Flour and grist	5	29	81
Do	do	do	Garland	do	1	20	15
Do	do	do	do	Saw	1	24	15
Do	do	do	do	Hones and whetstones	1	17	20
Do	do	do	Montgomery	Flour and grist	5	90	98
Do	do	do	Polk	Flour, grist, and saw	1	5	16
Total					39	422	778

a Chief of Engineers' Report, 1879.

Summary of the total utilized power on the western tributaries of the Mississippi river, below Dubuque.

Section.	Number of mills.	Total fall used.	Total horse-power of wheels.
		Feet.	
Eastern Iowa slope	340	2,812	15,410
Eastern Missouri slope	73	852	1,466
Missouri River basin	581	6,584	21,012
Arkansas River basin	288	2,608½	7,096
Red River basin	39	422	778
Total	1,321	13,278½	45,762

425

INDEX.

A.

Page.

Arkansas River basin—
- Area of ... 114
- Character of the surface of ... 114
- Climate of ... 115
- Description of the rivers of ... 117–133
  - Arkansas river ... 117–122
  - Canadian river ... 128
  - Neosho river ... 128–131
  - Sundry tributaries of the Arkansas river ... 132, 133
  - Verdigris river ... 131, 132
  - White river and tributaries ... 123–128
- General features of the streams of ... 116, 117
- Population of ... 115
- Summary of the total utilized power in ... 141

Arkansas river—
- Description of ... 117–122
- Discharge and drainage area of ... 119, 120
- Drainage areas of the tributaries of ... 122
- Elevation and slope of ... 119

B.

Bentonsport, Iowa, estimate of power at ... 102

Big Blue river—
- Description of ... 60–63
- Description of the tributaries of ... 63–65
- Estimated volume, horse-power, and drainage areas of the tributaries of ... 65

Big Sioux river—
- Description of ... 16–20
- Elevations on ... 17
- Estimated volume, horse-power, and drainage area of ... 20
- Improved power at Sioux Falls on ... 17–19

Big Tarkio river, description of ... 28

Big Thompson creek, description of ... 49

Black river, description of ... 125, 126

Blue Rapids, Kansas, power at ... 61, 62

Boone river, description of ... 106

Boulder creek, description of ... 49, 50

Boyer river, description of ... 24

C.

Cache la Poudre river, description of ... 48, 49

Canadian river, description of ... 128

Cedar Falls, Iowa, estimate of power at ... 95

Cedar river—
- Description of ... 93–96
- Estimated volume, horse-power, and drainage area of, and tributaries ... 97

Chariton river, description of ... 32

Clear creek, description of ... 50–52

Climate of the Missouri River basin ... 5–7

Coralville, Iowa, estimate of power at ... 90

Croton, Iowa, estimate of power at ... 101

Current river, estimated volume, horse-power, and drainage area of ... 126

D.

Dakota, power used on rivers of southeastern ... 21

Dakota river—
- Description of ... 14, 15
- Estimated volume, horse-power, and drainage area of ... 16

Delaware river, description of ... 59, 60

Des Moines river—
- Dams in, below Ottumwa ... 100
- Description of ... 98–105

Des Moines river—Continued. Page.
- Description of East Fork of ... 106
- Drainage areas and description of tributaries of ... 105, 106
- Estimated volume, horse-power, and drainage area of ... 105
- Estimated volume, horse-power, and drainage area of tributaries of ... 106

E.

Elkhorn river, description of ... 41, 42

F.

Floyd river, description of ... 22

G.

Gasconade river—
- Description of ... 81–83
- Estimated volume, horse-power, and drainage area of ... 83
- Power utilized on, and tributaries ... 83

Geology of Missouri River basin ... 2, 3

Grand river, description of ... 31

H.

Homestead, Iowa, estimated power at ... 91

I.

Illinois river, low-water volume of ... 86

Independence, Iowa, estimate of power at ... 89

Iowa river—
- Description of ... 89–92
- Estimated volume, horse-power, and drainage area of ... 92

Iowa slope, eastern—
- Altitude of points on ... 85
- Assumed rates of discharge for the rivers of ... 87
- Description of the rivers of ... 87–109
  - Cedar river ... 93–96
  - Des Moines river and tributaries ... 98–106
  - Iowa river ... 89–92
  - Maquoketa river ... 87, 88
  - Shell Rock river ... 96
  - Skunk river ... 97, 98
  - Wapsipinicon river ... 88, 89
- General characteristics of ... 84–86
- Power utilized on rivers of ... 107–109, 141
- Rainfall and temperature of ... 85

K.

Kansas river—
- Description of ... 56–59
- Description of the tributaries of ... 59–76
- Power used on, and tributaries ... 76, 77

Keg creek, description of ... 25

Keosauqua, Iowa, estimate of power at ... 102

L.

La Mine river, description of ... 77

Lawrence, Kansas, power at ... 57, 58

Little Blue river, description of ... 63, 64

Little Nemaha river, description of ... 54, 55

Little Sioux river, description of ... 22–24

Loup river, description of ... 42, 43

M.

Maquoketa river, description of ... 87, 88

Meramec river, description of ... 110, 111

Minnesota river—
- Drainage area of ... 19
- Low-water volume of ... 86

Mississippi river—
- Low-water volume of ... 86
- Summary of utilized power on the western tributaries of ... 141

Page.

Missouri river—
- Causes of floods in ... 12
- Characteristic features of ... 7–14
- Discharge of, at Saint Charles, for the year 1879 ... 14
- Drainage areas of ... 13
- Drainage areas of the tributaries of ... 10
- Elevations and slope of ... 11
- Estimated volume and horse-power of the northern Missouri tributaries of ... 33
- Estimated volume and horse-power of the western Iowa tributaries of ... 26, 27
- Explorations and surveys of ... 7, 8
- Physical features of ... 10, 11
- Power utilized on the northern Missouri tributaries of ... 33, 34
- Power utilized on the western Iowa tributaries of ... 27
- Summary of power utilized on the tributaries of ... 84
- Tributaries of, in northern Missouri ... 28–34
- Tributaries of, in western Iowa ... 21–27
- Tributaries on the east side of, below Yankton ... 14–34
- Tributaries on the west side of, below Fort Randall ... 35–84
- Value of the water-power of ... 13
- Variations in the volume of ... 11, 12

Missouri river basin—
- Amount of snow falling on ... 6
- Climate of ... 5–7
- Description of the rivers of ... 7–84
- General features of the prairie streams of ... 3, 4
- Geology of ... 2, 3
- Mountainous section of ... 1, 2
- Position and extent of ... 1
- Prairie section of ... 2
- Prevailing winds in ... 5
- Rainfall in ... 5–7
- Summary of total utilized power in ... 141
- Temperatures, mean, maxima, and minima, in ... 5

Missouri River valley, widths of ... 11

Missouri slope, eastern—
- Description of the rivers of ... 110–113
  - Meramec river ... 110, 111
  - Saint Francis river ... 111–113
- Summary of power utilized on the rivers of ... 113, 141

Moreau creek, description of ... 78

Mosquito river, description of ... 25

Mountainous section of the Missouri River basin ... 1, 2

N.

Nemaha river, description of ... 55, 56

Neosho river—
- Description of ... 128–131
- Drainage areas of the tributaries of ... 130
- Estimated volume, horse-power, and drainage area of ... 130
- Power utilized on, and tributaries ... 130, 131

Niobrara river, description of ... 35–37

Nishnabatona river, description of ... 25, 26

Nodaway river, description of ... 28, 29

North Platte river—
- Description of ... 43, 44
- Drainage areas of the tributaries of ... 52

O.

One Hundred and Two river, description of ... 30

Osage river—
- Description of ... 78–81
- Estimated volume, horse-power, and drainage area of ... 80
- Power used on, and tributaries ... 81

Ottumwa, Iowa, estimate of power at ... 104

Ouachita river—
- Description of ... 136–139
- Description of the tributaries of ... 139, 140

P.

Platte river—
- Description of ... 37–40
- Description of the tributaries of ... 40–54
- Drainage areas of the tributaries of ... 52
- Drainage from, underground ... 39
- Elevations on ... 38

Platte river—Continued.
- Estimated volume, horse-power, and drainage area of the tributaries of ... 53
- Power utilized on ... 53, 54
- Power utilized on the tributaries of ... 53, 54

Platte river, of Missouri, description of ... 29, 30

Prairie section of the Missouri River basin ... 2

Prairie streams of the Missouri River basin, general features of ... 3, 4

R.

Raccoon river, description of ... 105, 106

Rainfall in the Missouri River basin ... 5–7

Red river—
- Description of ... 133–136
- Description of the tributaries of ... 136–140
- Drainage areas of ... 133
- Estimated volume of ... 136

Red river basin—
- Description of the rivers of ... 133–140
  - Red river ... 133–136
  - Tributaries of the Red river ... 136–140
- Physical features of the country in ... 133–136
- Temperature of ... 134
- Rainfall of ... 135
- Power utilized in ... 140
- Summary of the total utilized power in ... 141

Republican river—
- Description of ... 65–69
- Description of the tributaries of ... 69, 70
- Estimated volume, horse-power, and drainage area of ... 69

Rock river, description of ... 20

S.

Saint Francis river, description of ... 111–113

Saline river—
- Description of ... 74, 75
- Estimated volume, horse-power, and drainage area of ... 75

Shell creek, description of ... 42

Shell Rock river, description of ... 96

Skunk river, description of ... 97, 98

Smoky Hill river—
- Description of ... 70–72
- Description of the tributaries of ... 72–75
- Estimated volume, horse-power, and drainage area of ... 72

Snow, amount of, falling on the Missouri River basin ... 6

Soldier river, description of ... 24

Solomon river—
- Description of ... 72–74
- Estimated volume, horse-power, and drainage area of, and tributaries ... 74

South Platte river—
- Description of ... 45–47
- Description of the tributaries of ... 47–52
- Drainage areas of tributaries of ... 52
- Estimated volume and horse-power of tributaries of ... 53

T.

Tama, Iowa, estimated power at ... 92

Temperatures, mean, maxima, and minima, in the Missouri River basin ... 5

Topeka, Kansas, undeveloped power near ... 58, 59

V.

Verdigris river, description of ... 131, 132

Vermilion river, description of ... 16

W.

Wapsipinicon river, description of ... 88, 89

Waterloo, Iowa, estimate of power at ... 95

White river—
- Description of ... 123–125
- Description and drainage areas of tributaries of ... 125, 126
- Discharge and drainage area of ... 124
- Estimated volume, horse-power, and drainage area of upper ... 125
- Power utilized on the, and tributaries ... 127, 128

Winds, prevailing, in the Missouri River basin ... 5

Y.

Yellowstone river, description of ... 8, 9

REPORT ON THE WATER-POWER

OF THE

OHIO RIVER BASIN

AND

OHIO STATE CANALS.

BY

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TABLE OF CONTENTS.

	Page.
LETTER OF TRANSMITTAL	1
OHIO RIVER BASIN	3
SURFACE FEATURES AND DESCRIPTION OF THE MAIN RIVER	3–7
POWER AT LOUISVILLE	7, 8
TRIBUTARIES OF THE OHIO RIVER	8–13
TRIBUTARIES OF THE ALLEGHENY RIVER	13–21
MONONGAHELA RIVER	21–23
YOUGHIOGHENY RIVER	23–26
CHEAT RIVER	26, 27
TYGART'S VALLEY RIVER	27, 28
WEST FORK OF THE MONONGAHELA RIVER	28–30
BEAVER RIVER	30–34
MUSKINGUM RIVER	34–38
TRIBUTARIES OF THE MUSKINGUM RIVER	38–42
LITTLE KANAWHA RIVER	42, 43
SCIOTO RIVER	43–46
GREAT MIAMI RIVER	46–56
WATER-POWER OF THE OHIO STATE CANALS	59–61
OHIO CANAL	61, 62
MIAMI AND ERIE CANAL	62–67

LIST OF ILLUSTRATIONS.

	Page.
SKETCH OF THE OHIO RIVER AT LOUISVILLE, SHOWING PROPOSED PLANS FOR OBTAINING WATER-POWER	7
THE YOUGHIOGHENY RIVER AT OHIO PILE FALLS	25
CROSS SECTION OF DAM AT MARIETTA	36
SKETCH SHOWING ACTION OF WATER IN PRODUCING SCOUR AND CONSTRUCTION FOR AVOIDING IT	50
PLAN OF WATER PRIVILEGE AT DAYTON VIEW, GREAT MIAMI RIVER	51

LETTER OF TRANSMITTAL.

BOSTON, MASS., *July* 16, 1883.

Professor W. P. TROWBRIDGE.

SIR: I have the honor to submit a report upon the water-power of so much of the Ohio River basin as could be examined during the limited period available before the stoppage of field-work. The investigations that were made were conducted during the winter of 1882–'83, and covered, it is thought, those streams having the greatest present importance with respect to water-power. It is desired to call attention to the principles observed in the estimates of flow and power, which are fully explained in connection with the report on the region tributary to Long Island Sound.

Very respectfully,

DWIGHT PORTER.

THE OHIO RIVER BASIN.[a]

SURFACE FEATURES, AND DESCRIPTION OF THE MAIN RIVER.

By the union of the Allegheny and Monongahela rivers at Pittsburgh the Ohio river is formed, with a drainage basin at that point of between 18,000 and 19,000 square miles, which, after a course of nearly a thousand miles to the southwest, is increased to about 214,000 square miles at the junction with the Mississippi. The principal streams which contribute to this increase are, on the north side, the Beaver, Muskingum, Scioto, Great Miami, and Wabash rivers, and on the south side, the Little Kanawha, Great Kanawha, Big Sandy, Licking, Kentucky, Green, Cumberland, and Tennessee. The head-waters of the Allegheny are in northern Pennsylvania and southwestern New York; those of the Monongahela, nearly 250 miles distant, in West Virginia. The eastern watershed line of the Ohio, therefore, cuts entirely across the state of Pennsylvania, at a distance from the western border ranging from 80 miles in the south to about 130 miles in the north. Passing out of this state, the northern boundary of the river basin runs through New York, Ohio, and Indiana, being carried in the latter state around the upper waters of the Wabash nearly to the Michigan line, and considerably more than 200 miles north of the main river itself; it then enters Illinois and strikes southerly through that state to the mouth of the Ohio at Cairo. The southern boundary runs from Pennsylvania across a corner of Maryland, embraces nearly all of West Virginia, forming in part the dividing-line between that state and Virginia; it crosses the southwestern portion of the latter state and the western part of North Carolina, and by the Tennessee basin is extended down into Georgia and Alabama, reaching there a distance of 300 miles south of the Ohio; it continues from Alabama across the adjacent northeastern corner of Mississippi, and finally traverses the extreme western portions of Tennessee and Kentucky.

The vast extent of country included within the limits described possesses great variety of surface features, and these affect correspondingly the character of the streams draining the different sections. For 700 or 800 miles the general course of the eastern and southern boundary of the drainage basin of the Ohio lies along the crests of the Alleghany Mountain ranges, peaks of which attain in North Carolina elevations of 6,000 feet and over. Down the western slopes of these mountains there flow streams to join the Allegheny, Monongahela, Kanawha, and Tennessee rivers, running through a country often of the wildest description, but magnificently timbered, and rich in deposits of coal, iron, building-stone, copper, gold, and other minerals. Among these mountains many of the streams have a very rapid fall, and are subject to large and frequently sudden fluctuations in volume, rendering them in consequence unreliable for power. The country being sparsely settled, they are utilized to but a comparatively small extent, and that mainly by saw- and grist-mills. Advancing to the west and northwest from this mountainous district we find it succeeded by a beautiful undulating country, fertile, well settled, and cultivated. To the north of the Ohio river, in the states of Ohio and Indiana, the surface continues for some distance quite broken, and then subsides into gently-rolling land, once heavily wooded, but now cleared, and very productive. After leaving the mountains the streams heading in them gradually increase in volume by accessions from tributaries, and at the same time lose in rapidity of descent, until in their lower courses most of the larger affluents of the Ohio have but a small slope, and are either navigable or capable of being made so without much difficulty. To illustrate the changed character which some of the streams assume, it may be mentioned that the Cheat river, flowing through the mountains of West Virginia, falls 2,400 feet in the last 80 miles of its course, while the Monongahela, into

a Owing to the stoppage of field operations in January, 1883, the examination of rivers in this region was confined to those above and including the Great Miami on the north side of the Ohio, and to the Monongahela and Little Kanawha on the south side.

which it empties a little west of the Laurel Hill range, descends but 75 feet in the 90 miles from the mouth of the Cheat to Pittsburgh. Brief data regarding some of the principal rivers flowing into the Ohio, in part taken from Humphreys and Abbot's report, are given below:

Name of river.	Drainage area.	Remarks.
	Sq. miles.	
Allegheny river at Franklin	5,667	Entire length, about 325 miles. Navigable about half the year for small steamers to Franklin, 123 miles above Pittsburgh. Fall from Olean, New York, to Franklin, Pennsylvania (132 miles), 446 feet; thence to Pittsburgh, 279 feet, or 2.27 feet per mile. Country drained, in general mountainous and rough, with heavy growth of timber. Above Corydon, 209 miles from the mouth, power is used at intervals on the main river for saw-mills.
Allegheny river at mouth	11,107	
Monongahela river at Morgantown	2,737	Basin in part mountainous and timbered, and in part rolling country cleared and cultivated. Fall from mouth of West fork to Pittsburgh (say 123 miles), 132 feet, or an average of 1.07 foot per mile. The present system of locks and dams is being extended to give navigation to Morgantown, 102 miles from the mouth. Thence to Fairmount, 20 miles or so above, the stream is utilized for power by several small grist-mills.
Monongahela river at mouth	7,625	
Beaver river	3,030	Falls about 130 feet from New Castle to the mouth. Not navigable, but utilized within a few miles of the mouth for power by a considerable number and variety of manufacturing concerns.
Little Kanawha river	2,290	Fall from Bulltown to mouth, 199½ feet in 130¾ miles, or an average of about 1½ foot per mile. Four-foot slack-water navigation is maintained to Burning Springs, 40 miles from the mouth, and is being extended somewhat above by the national government. A small grist-mill utilizes power at one of the dams. The flow of the stream is unreliable, and is subject to great and remarkably sudden fluctuations. Lumbering is the chief industry on the river.
Great Kanawha river	.....	Fall in 89 miles above mouth is given by Humphreys and Abbot as 86 feet, or an average of about 1 foot per mile. By a system of locks and dams, part of the latter fixed and part movable, the national government is engaged in improving the navigation of the river, with the aim of insuring a continuous depth of 7 feet from the mouth to the upper river, naturally tributary to which are magnificent coal-fields.
Muskingum river	7,740	Navigation by means of locks and dams maintained to Dresden, 91 miles from the mouth, by the state of Ohio. Fall in same distance 130 feet, an average of 1.4 foot per mile. Power utilized to a moderate extent at a number of the dams.
Scioto river	6,400	Not navigable, and not utilized for power below Columbus. Drains a farming region. Fall from Columbus to the mouth, 225 feet in 110 miles, or an average of about 2 feet per mile. Greatest elevation in drainage basin between 1,500 and 1,600 feet above sea-level.
Great Miami river	5,400	Fall from Dayton to the mouth, 298 feet in 77 miles, or 3.9 feet per mile on the average. River not navigable, but has been improved for power at numerous points, and sustains important manufacturing interests, the most prominent industry along its course being the manufacture of paper.
Big Sandy river	3,950	The main river is navigable, and this, together with the principal forks, Louisa and Tug, is being improved by the United States government for navigation by the removal of rocks, fallen trees, and other obstructions. Steps have also been taken to inaugurate a system of slack-water navigation, and a site for a dam has been fixed upon near the junction of the forks.
Licking river	3,870	Fall from West Liberty, Morgan county, to the mouth, 310 feet in 231 miles, an average of 1.34 foot per mile. Flow very variable. Navigation is carried on to a small extent. Surveys have been made and are still in progress (1881) to determine the practicability of establishing slack-water navigation.
Kentucky river	7,870	Falls 228 feet in the 258 miles from the mouth of the Middle fork to the mouth of the main river, an average of about 0.9 foot per mile. Lower 95 miles of river improved many years ago for navigation, by state of Kentucky, by means of locks and dams. These are now being repaired by the national government.
Green river	.....	Average slope for 175 miles above the mouth given by Humphreys and Abbot as 4½ inches per mile. Slack-water navigation is maintained from the mouth to Bowling Green, through the distance above mentioned, by means of five locks and dams, originally built by the state of Kentucky, but now operated by the Green & Barren River Navigation Company.
Wabash river	.....	Fall given by Humphreys and Abbot as 57 feet in the 91 miles from the mouth of White river to the Ohio; and as 385 feet in the 370 miles below the mouth of Little river, giving an average descent for the entire distance of 0.96 foot per mile, and below White river 0.63 foot per mile. The lower river is regularly navigable, and improvements and surveys are in progress under the national government, with the view of extending low-water navigation up the river.
Cumberland river	.....	Rises in the Cumberland mountains and descends rapidly to the plains, after which it flows more gently to the falls. It is then inclosed between high bluffs, and has a rapid current as far down as Laurel river. Here begins the coal region, which extends 13 miles down the stream. The principal obstructions to navigation below are Smith's shoals, 358 miles above Nashville, where there is a total descent of 55 feet in 8 miles on four shoals. From Nashville to the mouth, 192 miles, the average fall is 0.41 foot per mile. Between the mouth and Nashville the river is navigated during six months in the year by steamers of from 300 to 500 tons and less. For nine or ten months in the year it is navigable over the same distance for boats of 20 inches draught. Above Nashville navigation extends, for from four to six months in the year, for steamers of 3 feet draught, 358 miles to Point Burnside, crossing-point of the Cincinnati Southern railroad. The Falls of the Cumberland have been surveyed and reported on under date of February, 1879, by Mr. Samuel Whinery, United States assistant engineer (see *Report of Chief of Engineers*, 1879). As described by Mr. Whinery, "The great falls of the Cumberland river are situated in the southwestern part of Whitley county, Kentucky, about 60 miles by river above Point Burnside, and 12 miles east of the line of the Cincinnati Southern railroad. The river at and above the falls is a rapidly-descending mountain stream carrying a large volume of water at flood tide, and shrinking to a mere brook during extremely dry seasons. Geologically, the fall is situated in the 'millstone grit' or 'cliff rock' of the Upper Coal Measures, through which it has cut a deep and narrow chasm, with walls often 300 feet high and almost perpendicular." The survey extended from a point 1 mile above, to a point about 1⅝ mile below, the great fall, covering a descent of 84.5 feet in the river, of which 51.1 feet was assigned to the great fall.
Tennessee river	.....	The Holston river, the true source, rises in the Alleghany mountains, 2,500 feet above sea-level. It is a rapid stream, running over a rocky bed and through a narrow valley. It is joined successively by the French Broad and Clinch rivers. Islands are numerous. The river is contracted in several places by high promontories and is made deep and rapid. The course is then more direct, and the current is gentle to Muscle shoals, which for about 23 miles, between Florence and Decatur, Alabama, obstruct navigation. The total fall in 36.5 miles, including these shoals, is given by Humphreys and Abbot as 164 feet. Except at Muscle shoals, there is continuous navigation from Chattanooga to the mouth of the river, 453 miles. The improvement of navigation at the shoals, and also at points above Chattanooga, is being prosecuted by the national government.

There can be no question that, in their upper courses, above the limits of navigation, the various tributaries on the south side of the Ohio, and their own affluents, present in the aggregate much available water-power, but no opportunity was afforded to examine personally any of those below the Monongahela. Those to the north of the Ohio are already largely in use, and will admit of much further development. The powers offered by the latter, though well suited to the demands of ordinary manufacturing, are not, individually, of great magnitude, for the reason that the fall at command on the principal streams is nowhere very large, while their volume of flow is on a rather small

scale relatively to the extent of area drained, and in the dry season sinks in many cases very low; so that, if their value is to be estimated on the basis of permanently reliable power, they can not take a high rank. There are probably no privileges on the northern tributaries of the Ohio which can be depended upon at all times for more than 1,000 or 1,500 effective horse-power, and even such are of unusual occurrence.

The proportion of the rainfall which is discharged by the streams is, generally speaking, considerably less in the Ohio River basin than in New England and New York, but too little is known to admit of much certainty either in statement or in estimate regarding the real numerical ratio. Humphreys and Abbot estimated the average annual rainfall of the entire basin to be about 41½ inches, and 24 per cent. of this to be carried off by the river. The climate, the deep soil, the permeable underlying strata, and the open character of much of the country drained, denuded of its timber, doubtless all have an influence in producing a low percentage. The streams also suffer from being deficient in that natural regulation of flow afforded in some sections of the United States by an abundance of springs, lakes, and swamps. The rainfall and temperature must, of course, vary widely over so extended a region as we are considering. The following table does not exhibit the extremes, nevertheless it gives the results of observations of these phenomena at a number of prominent points, and will convey a fair idea of their range over different portions of the river basin:

Records of rainfall and temperature at points in the Ohio River basin. (*a*)

Locality.	Altitude above ocean-level.	RAINFALL. Number of years of observation.	Spring.	Summer.	Autumn.	Winter.	Year.	TEMPERATURE. Number of years of observation.	Spring.	Summer.	Autumn.	Winter.	Year.
	Feet.		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*		*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*
Jamestown, New York (in upper Allegheny basin)	1,454	8	9.86	12.16	11.23	9.91	43.16	3	44.41	66.97	48.65	24.69	46.18
Pittsburgh, Pennsylvania	840	16	8.86	10.72	8.21	7.61	35.40	12	49.68	72.41	54.03	31.64	51.94
Kanawha, West Virginia (in Great Kanawha basin)	.....	.....	.....	.....	.....	.....	.....	8	54.38	71.40	54.65	36.66	54.27
White Sulphur Springs, West Virginia (in Great Kanawha basin).	2,000	5	10.07	10.63	7.30	9.54	37.54	.....	.....	.....	.....	.....	.....
Wytheville, Virginia (in upper basin of Great Kanawha)	2,287	9	10.38	11.97	8.46	9.23	40.04	4	51.35	70.33	51.82	34.93	52.11
Asheville, North Carolina (in upper basin of Tennessee river)	2,250	6	10.33	13.90	6.43	9.05	39.71	4	52.60	70.56	54.26	37.91	53.83
Huntsville, Alabama (in middle basin of Tennessee river)	600	14	14.29	15.36	9.86	15.84	55.35	13	59.96	75.62	59.80	42.15	59.38
Knoxville, Tennessee (in upper basin of Tennessee river)	1,000	7	14.52	14.15	8.90	14.01	51.58	6	55.80	74.73	58.62	37.82	56.74
Nashville, Tennessee (on Cumberland river)	533	11	14.33	12.73	11.50	13.22	51.78	6	59.85	76.32	57.42	39.67	58.32
Danville, Kentucky (in Kentucky River basin)	900	14	12.30	11.95	8.29	11.11	43.65	12	56.28	75.58	58.56	37.84	57.07
Louisville, Kentucky	450	7	13.15	12.27	8.99	13.40	47.81	4	55.71	73.96	55.79	37.34	55.70
Bellefontaine, Ohio (near head-waters of Scioto and Great Miami).	1,040	7	10.30	12.09	7.60	8.13	38.12	3	48.87	72.61	51.89	26.25	49.91
Cincinnati, Ohio	580	42	11.17	12.67	9.29	9.83	42.96	36	54.13	75.24	55.21	34.28	54.72
Marietta, Ohio (mouth of Muskingum river)	580	48	10.74	12.69	9.55	9.52	42.50	50	51.98	71.29	52.85	32.84	52.24
Steubenville, Ohio	670	40	10.59	11.88	9.68	9.00	41.15	40	50.99	72.60	52.52	31.22	51.83
Logansport, Indiana (in upper Wabash basin)	600	4	11.33	8.30	10.44	8.07	38.14	5	49.60	73.89	51.51	27.64	50.66
Indianapolis, Indiana (in Wabash basin)	698	12	13.40	11.04	8.05	8.86	41.35	6	49.34	72.64	51.96	28.71	50.66
New Albany, Indiana	553	3	9.35	8.86	9.40	12.22	39.83	4	51.16	73.91	54.63	33.94	53.41
Mattoon, Illinois (in Wabash basin)	740	4	19.95	16.46	8.00	12.62	57.03	.....	.....	.....	.....	.....	.....

a From the Smithsonian tables.

The chief disadvantages to the utilization of power on those northern tributaries of the Ohio which were visited arise from a liability to an insufficient supply of water in summer and fall; from the occurrence of heavy freshets, accompanied often at the close of winter by runs of thick ice, endangering hydraulic works; from the backwater caused by those freshets, which lessens the fall, and remains long according as the descent in the stream below is small and the country drained above is flat; and from the difficulty of securing rock foundation for dams. With reference to this latter objection it may be said, however, that good gravelly beds are common, and with a suitable construction of dam should be entirely safe. The principal application of power on these streams has thus far been in flouring-, grist-, and saw-mills; but on certain rivers, notably the Great Miami and the Beaver, general manufacturing has become well established.

The Ohio river itself presents but one opportunity for the use of water-power on a large scale by ordinary methods, namely, at the Louisville falls, which will be described farther on. A few miles below Pittsburgh the national government has been building a movable dam, known as the Davis Island dam, designed to improve the navigation of the river by assuring at all times a depth of 6 feet above to the city. It extends in two sections from either shore to the island, and with the river unimproved below will have a lift in low water of about 10 feet. If this system of improvement were to be continued down the river as proposed, the lift at the Davis Island dam would be reduced to about 6 feet. In low water, when the dam will be upright, boats will pass through a lock next the right bank. In high water, however, the dam will lie flat on the river-bed, being protected by low sills

from the force of the current, which at such times is very rapid, probably reaching a velocity of from 7 to 9 miles per hour. The river-bed is composed at this locality of sand, gravel, and bowlders, and for the dam an artificial bed of concrete was made. The structure itself consists of a great number of wooden wickets hinged at the base and supported when raised by iron braces, these also hinged at one end to the under face of the wickets and with their lower ends resting in slots. The wickets are raised and lowered from an iron truss bridge formed by bents hinged at the base so as to revolve in a plane transverse to the stream, while the wickets themselves revolve with the stream. In high water the bridge, as well as the dam, rests on the river-bed, so that no obstruction is offered to the current or to the free passage of boats at any point. So long as the dam is in position, or for say seven months in the year, there must evidently be a considerable power going to waste here, although in very low stages of water it would not probably exceed 3,000 or 4,000 theoretical horse-power, even with 10 feet of fall and the entire volume of the Ohio. Works for employing the power thus afforded could, it is said, conveniently be located out of reach of any but extreme rises in the river; but there is at present no settlement at this point, the hydraulic improvements would be expensive, and this, together with the fact that the privilege could be utilized for only so small a portion of the year, and that during much even of that time the full fall could not be realized, would doubtless be serious obstacles to its development.

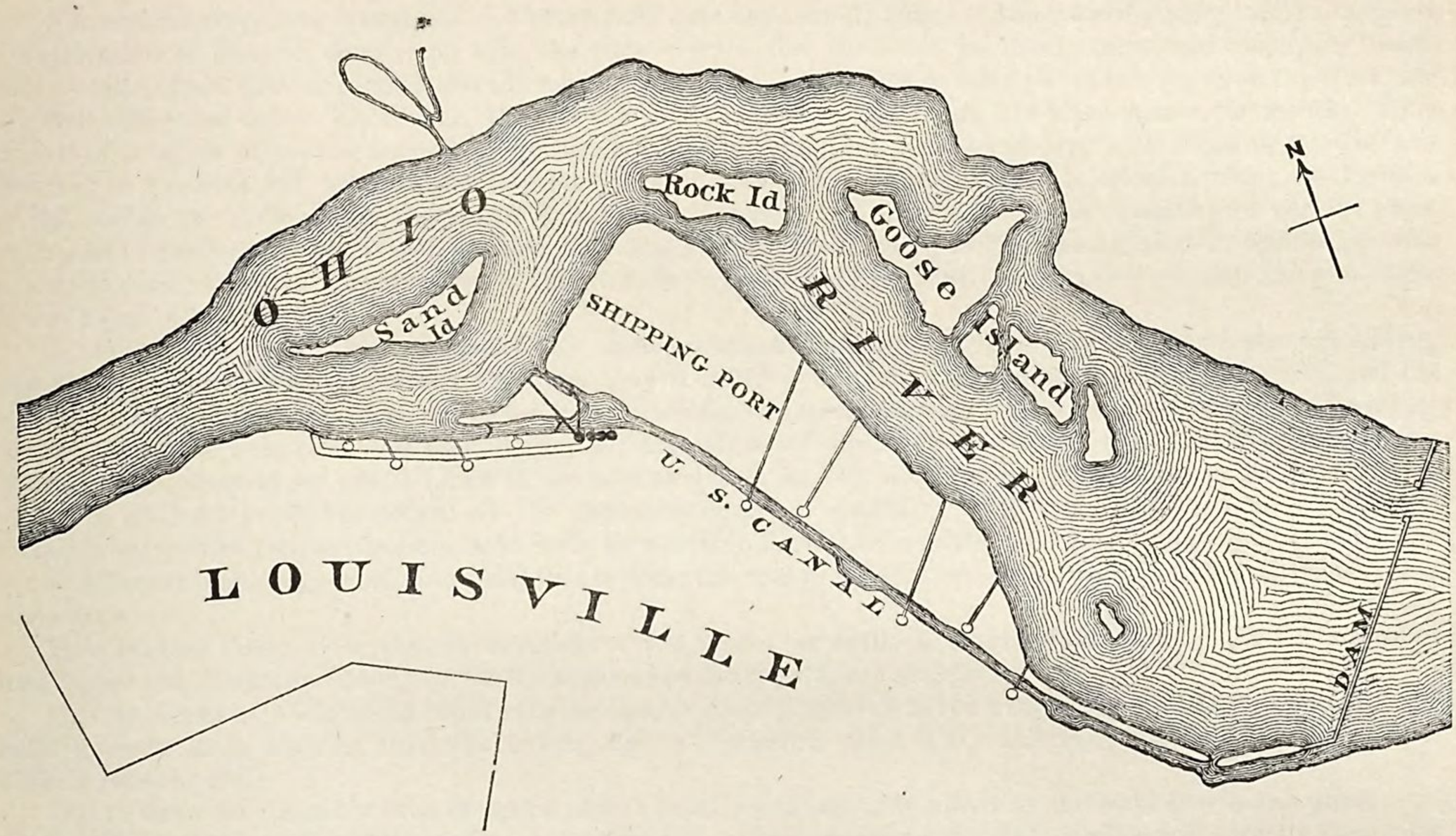
The employment of current-wheels for obtaining power is, of course, possible, and there is said to have been one of these, years ago, on the upper river, but there is no likelihood of their coming into common use here at present; and sufficient has been said regarding their value in another part of this report. The fall in the Ohio is in general slight, and no opportunity exists, as on some western rivers, for diverting water through sloughs across long bends, and so taking advantage of the intermediate descent. This river does not form sloughs of the nature referred to, or "cut-offs", as do the Mississippi, Missouri, Arkansas, and other rivers. At certain points long loops have formed, and at one of these, in the vicinity of Evansville, it is thought possible that protective measures may have to be taken to guard against a cut-off; but usually the projecting points of land which are left have within a rocky shoulder, preventing the actual cutting through of a channel.

Table of elevations on the Ohio river.(*a*)

Locality.	Distance from mouth of river.	Elevation of low water above ocean-tide.	Distance between points.	Fall between points.	Fall per mile between points.	Remarks.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	
Pittsburgh	967	701.640				Elevation assumed as 699.20 feet by Mr. James T. Gardner (see *Elevations of Certain Datum Points on the Great Lakes and Rivers and in the Rocky Mountains*).
Mouth of Beaver river	942	671.570				
Steubenville	899	640.518				Elevation assumed by Mr. Gardner as 630.77 feet at low water.
Marietta	796	569.821				
Mouth of Little Kanawha river	784	563.694	598	308.340	0.516	
Mouth of Great Kanawha river	704	514.554				
Portsmouth	614	467.526				Elevation assumed by Mr. Gardner as 479 feet at low water.
Cincinnati	501	430.800				Elevation assumed by Mr. Gardner as 439.74 feet at low water.
Mouth of Great Miami river	480	426.617				
Carrollton	426	403.828				
Louisville falls, head	369	393.300	4	25.700	.....	The descent at the falls proper has been determined by other surveys, and is usually stated as about 26 feet in about 2 miles.
Louisville falls, below foot	365	367.600				
Mouth of Green river	192	319.056	365	92.600	0.254	
Mouth of Wabash river	129	304.313				
Cairo	0	275.000				As reported from the office of the Mississippi River commission, "The zero of the United States engineers' gauge at Cairo, Illinois, is 269.58 feet above mean tide at Biloxi, Mississippi, and the lowest recorded stage of water at that point occurred December 25, 1871, when the surface of the water was 1 foot below the zero of the gauge. Its elevation above mean tide was therefore 268.58 feet. The elevation of mean tide has not been finally adopted [February, 1884], and the above elevations are subject to small corrections."

a The elevations in the third column of this table are taken from Mr. W. Milnor Roberts' report, dated April, 1870, on a survey of the Ohio river—*House Ex. Doc. No. 72, Forty-first Congress, third session*—and can not be regarded as entirely correct; Major William E. Merrill, Corps of Engineers, has discovered an error of 8 feet in the elevations between Pittsburgh and Wheeling.

As shown by the data of the preceding table, the total descent in the Ohio, at low water, from Pittsburgh to Cairo, is not far from 430 feet in 967 miles, an average of about 0.44 foot per mile for the whole distance. The river gradually increases in width at low water from 1,000 feet in its upper course to about 2,500 feet near the mouth. At such a stage it is described as a succession of long pools and ripples, with current alternately sluggish and rapid. A large commerce is carried on by means of steamers, barges, and other craft, but navigation is seriously interfered with by low water, and continuous communication from Cairo to Pittsburgh, for boats of considerable draught, has hitherto been practicable during only about four months in the year. On the upper river the bars are mainly of gravel, and, on the lower river, of shifting sand.



SKETCH OF THE OHIO RIVER AT LOUISVILLE, SHOWING PROPOSED PLANS FOR OBTAINING WATER-POWER.

There are usually three important rises in the Ohio during the year—one in February, caused by rains and melting snow; one in May or June, due to heavy rains; and a third occurring in late fall, not very regular in the date of its appearance, and caused by rains. The first of these is the heaviest, and sometimes produces widespread destruction of property. The ordinary oscillation, in general along the course of the river, between high and low water, is given by Humphreys and Abbot as not over 25 feet, while the extreme is placed at about 45 feet; but at particular localities these figures are exceeded. Thus, at the mouth the extreme range is over 50 feet; in February, 1832, the river was 64 feet above low water at the foot of the Louisville falls, and in February, 1884, it reached a height at Cincinnati of 71 feet 0.75 inch above low water. The river commonly freezes about Christmas, and continues frozen sometimes as long as four weeks, and in 1855 remained frozen at Louisville for 65 days. On the rising of the streams, toward the close of winter, great fields of floating ice are brought down by various tributaries of the Ohio, especially by the Allegheny and Monongahela, though the ice from these latter rivers is well broken up against the bridge-piers at Pittsburgh.

POWER AT LOUISVILLE.

For reasons elsewhere stated, the Louisville falls were not visited; but as it seems hardly permissible to neglect a description of them in connection with the Ohio river, a few facts will be briefly mentioned regarding them, taken mainly from various reports already made upon the subject. These falls, the only ones upon the river, are situated 600 miles below Pittsburgh, 135 miles below Cincinnati, and about 370 miles above the mouth. They consist of a series of rapids, formed by irregular ledges of limestone rock, extending a distance of 3 miles, and covering in 2 miles a fall, in low water, of about 26 feet, four-fifths of which occurs in about 1 mile. At the head of the rapids the government has a low dam reaching across the stream, with the exception of certain gaps, built part of the way of a movable pattern, and designed to be extended of the same type. In connection with this improvement a canal some 2 miles in length follows down the Kentucky side of the river, and accommodates boats in passing the rapids.

Louisville is a wealthy and beautiful city of about 125,000 inhabitants, enjoying a large trade and having important manufacturing interests. The great power existing in the river immediately before the city, and the advantage which would accrue to the latter from its utilization, have not been overlooked, and various plans for its development have been proposed and discussed. But while the size and value of the power are evident, the cost of such improvements as would make it actually available for use appears so large as to render doubtful the receipt of a direct profitable return on the necessary outlay of capital. So far as ascertained, no detailed and complete surveys and estimates have been made by which to show the probable expense of improvement under any of the different plans suggested, and until this is done the real practicability of the work must remain a matter of conjecture.

Four leading designs for the development of the power, as outlined by Morris S. Belknap, C. E., in a paper read before the American Society of Civil Engineers in May, 1873, are as follows:

(1.) By means of a hydraulic canal running approximately parallel to the canal now in use for navigation, the mills to derive their supplies from the former and to discharge either into a tail-race extending parallel to it, or directly into the river.

(2.) To draw for the mills from the government canal, discharging in either of the ways above described.

(3.) To draw from a canal carried as a continuation of the government canal, discharging directly from each mill into the Ohio.

(4.) To draw from the government canal at its lower end for the supply of turbines and other hydraulic machinery to be stationed there, the power developed to be distributed by wire cables to the various mills and factories.

Still another plan is said to have been considered, namely, the carrying of a hydraulic canal off into the city, or around it, at a considerable distance from the river.

Altogether there has been expended on the navigation canal more than $4,000,000, and by comparison the necessarily great expense involved in the first plan is opposed to its adoption. Notwithstanding this fact, it has important advantages, and is regarded by prominent authority as the most practicable of any of the designs. The second, third, and fourth methods of improvement require the withdrawal of water from the government canal, for which act permission must be obtained. The transmission of hydraulic power by cables, while in successful operation at such points as Lockport and Rochester, is there confined to small powers, and the experience at the latter point in transmitting large powers, say of 200 or 300 horse-power, is unfavorable to that system, while in an enterprise of such magnitude as the utilization of the Louisville falls there should exist the ability to supply powers of large as well as of small size. By means of a low wing-dam of rip-rap next the Indiana bank sufficient water is diverted to furnish power, through the medium of a wire cable, to a mill on the bluffs, and there is reported to be a trifling use of power on the Kentucky side of the river; nevertheless, the Louisville falls are essentially unemployed for manufacturing-purposes.

It will naturally be asked: How large is the power to be obtained from the falls of the Ohio? But to this question perhaps no very definite answer can now be given. The volume of the Ohio at Louisville, during an ordinarily low stage, was stated by Mr. Belknap to have been shown by observation to be about 7,750 cubic feet

per second, corresponding, with the full fall of 26 feet, to about 22,900 theoretical horse-power. But of this volume a certain portion must be required for lockage in the government canal, while another and much larger portion must escape through the gaps in the dam. Just what remainder there would be available for power is not accurately known. In an estimate made by Mr. John Zellweger, constructing engineer of Louisville in 1876, it was roughly assumed that one-third the entire flow of the stream at such a stage could be utilized, yielding say 7,600 theoretical horse-power. For nearly all the year the discharge of the river is greatly in excess of the figures given, but, owing to the fact that as it increases from low stages the level of the water at the head of the falls rises much less rapidly than that at their foot, the net fall is thereby reduced. This action is largely due to the contraction of the river at the "narrows", some 60 miles below Louisville. As stated by Mr. Zellweger, "The fall, or difference in water-level above and below the locks, does not decrease regularly as the river rises, but at first decreases slowly until the upper gauge marks about 7 feet; then it commences to decrease more rapidly until the gauge indicates about 14 feet. Above this the fall is reduced slowly, and remains nearly permanent for the high stage of water. In the year 1875 the upper gauge read off less than 7 feet, and the fall was over 22½ feet, for 126 days; less than 12 feet, and the fall was 6¾ feet (or over), for 300 days; less than 14 feet, and the fall was 3½ feet (or over), for 327 days." The year mentioned was one of unusual rainfall in this section of the Ohio valley. The fall was less than 6 feet for about 25 days in March, a total of 25 days in July and August, 4 days in December, and 3 days in April, in the two latter months the diminution below 6 feet being small in amount.

Mr. Belknap gives 12 feet by the gauge above the falls as the stage at which nearly all fall is lost and the water-surface has its normal slope, the rise below the falls being about three times as rapid as above them; and states that, as the average of years of observation by authorities in charge of the government canal and of the water-works, the following differences of level have been found to exist: For 21 days in the year, practically no fall; for 11 months and 9 days, 6 feet and over; for 9 months and 21 days, 13 feet and over; for 3 months and 17½ days, 26 feet.

For between 9 and 10 months in the year, therefore, a fall of 13 feet and upward is available. During that period there is, of course, a wide variation in the volume of the river, though no data are at hand showing directly its value in cubic feet. But, by a consideration of the probable curve of discharge of the Ohio at this point, the range may be roughly estimated to be from 8,000 to at least 130,000 cubic feet per second. (*a*) Assuming, however, for the lower limit the figures already quoted from Mr. Belknap's paper, we have a variation from 7,750 cubic feet per second in what is termed an ordinarily low stage with 26 feet of fall, to 130,000 cubic feet per second, with say 13 feet of fall; or from 22,900 to 192,000 theoretical horse-power. Reckoning an efficiency of 75 per cent., this corresponds to a range, in round numbers, of from 17,000 to 144,000 effective horse-power. That is to say, excluding from two to three months of highest water, in which the fall varies from 13 feet down to practically nothing, and for half of which time it would probably be found less than 6 feet, the entire volume of the river would yield, in the average of years, an effective power ranging, for different stages, between 17,000 and 144,000 horse-power. But since, as has been noticed, a large proportion of the discharge must, under the present arrangement of dams, run entirely to waste, while part of the balance is necessarily reserved for lockage, it is evident that the figures stated must be greatly reduced before arriving at the values pertaining to practical utilization of the falls for hydraulic purposes.

The fact that there is a certainty of interruption during a part of the year by high water, rendering necessary the introduction of auxiliary steam-power by all important establishments, is, without doubt, unfavorable to this site. It seems unquestionable, also, that the expense of suitable hydraulic works would be heavy. Nevertheless, when the location of the power is considered, at a great, wealthy, and rapidly growing city, upon a river supporting a magnificent traffic yet in its infancy, its importance becomes apparent; and even if the enterprise of developing it were to afford but a very slight direct profit upon the required investment, the indirect advantages which would result from the building up of large manufacturing works can not be doubted. The question, however, as to how great an outlay could be endured without rendering it impossible to lease power at a price which would admit of successful competition with similar undertakings elsewhere, and especially with steam-power derived from cheap coal, is one of finance, and one demanding in its decision exercise of thorough knowledge and sound judgment.

TRIBUTARIES OF THE OHIO RIVER.

THE ALLEGHENY RIVER.

Drainage areas.

	Square miles.
At Port Allegheny	219
At Olean, below Olean creek	1,096
At Salamanca	1,556
At Warren, below Conewango creek	3,045
At Franklin, below French creek	5,667
At Pittsburgh, mouth of river	11,107

a The drainage area above Louisville is about 91,000 square miles. On this area the average rainfall may be estimated to be, in spring 10 inches, in summer 11, in autumn 9, in winter 11, and for the year 41.

This river, the principal one in the formation of the Ohio, takes its rise in Potter county, northern Pennsylvania, close by the sources of the Susquehanna and Genesee. Thence to the junction with the Monongahela at Pittsburgh the course pursued is very irregular. The stream first flows westerly into McKean county, and then, making a bend to the northward, passes into New York state and across the southern part of Cattaraugus county. At Salamanca, in that county, the direction of flow turns toward Pennsylvania again, and thence to Pittsburgh its course may be called southwesterly, although it is not maintained with much persistency. The length of the Allegheny, following its bends, is not far from 325 miles, and the area of its drainage basin is, in round numbers, 11,000 square miles. The section of country thus comprised lies largely upon the western slope of the Alleghany system of mountains, and possesses, in the main, an extremely rough and broken surface, made up of high hills or mountains, the summits of which reach, in southern New York, elevations of 2,500 or 3,000 feet above tide, while between the hills are proportionately deep valleys. As the limits of the basin to the west of the main river are approached, the mountainous character is lost, though the surface is still hilly or rolling.

Pittsburgh, at the mouth of the river, has grown with remarkable speed, and had in 1880 a population of 156,000. Scattered along the course of the river above are a number of cities, boroughs, and villages, of considerable importance, the principal among them being, in order passing up stream, Freeport, population 1,600; Kittaning, 2,600; Franklin, 5,000; Oil City, 7,300; Tidioute, 1,300; Warren, 2,800; Salamanca, 2,500; and Olean, 3,000. Much of the country naturally tributary to the river, however, and especially that lying to the east and southeast of its upper course, is but very sparsely settled. Means of communication by railroads are tolerably good, and along the immediate course of the river such routes form a continuous line from the mouth nearly to the head-waters, though not existing under one management. Great activity pervades this portion of Pennsylvania on account of the many enterprises for developing its natural resources, which are very great. The Allegheny river runs through the midst of the oil region. Many of the hill-sides fairly bristle with derricks erected over the wells; the product is conveyed great distances in continuous lines of pipe, and in certain localities, as for instance in the vicinity of Olean, may be seen large numbers of iron tanks dotting the fields for a long distance and used for storage. The back country is clothed with valuable forests of timber, which is cut and rafted down the streams in immense quantities. Formerly pine was the principal variety cut, but now, along the upper waters of the main stream at least, the supply of this has become much reduced, and hemlock is the chief reliance. The lumber rafts are made up of "pieces" containing from 20,000 to 30,000 feet each; from Olean the rafts usually start with from 100,000 to 150,000 feet, and are from time to time "doubled up" as they get farther down the river. Besides oil and timber, the section drained by this river is rich in accessible quarries of limestone and building-stone, and in deposits of coal, iron, and glass-sand. The undertakings aimed at developing the particular resources mentioned give rise in turn to numerous other industries; various new railway lines are projected, and the cities are filled with an eager, shifting throng of managers, projectors, and speculators.

For about half the year the river is navigable for small steamers to Franklin, 123 miles above Pittsburgh. The actual amount of transportation by water, however, is small, and the freight is mainly confined to oil and coal. Within a few years the course from Olean down to within 30 miles of the mouth has been examined and in part surveyed by Mr. Thomas P. Roberts, United States assistant engineer, in order to determine its value for navigation, and the best method of improving it. (*a*) The plan proposed for the present is to clear the channel of obstructing rocks, and to secure sufficient depth at shoals by constructing wing-dams, the estimated cost of the improvement for the 188 miles below Warren being $133,650. The sum of $10,000 having been appropriated by Congress, work was begun upon the lower river in the summer of 1879.

Nothwitstanding its importance as a river which receives the drainage from a wide extent of country, much of which is of an elevated and even mountainous character, the Allegheny has comparatively small value for water-power. The area of the entire basin, as has been said, is about 11,000 square miles; but if we assume that by improvements navigation may be established as far north as Warren, there remains above that point but little more than 2,000 square miles to contribute by its drainage to the volume and available power of the main stream. The fall in the river is also too small in that section to admit of the establishment of many water-privileges. Of the 325 miles' entire length of the river, 255 miles are included between Olean, New York, and the mouth; but the total fall in this interval, comprising about 80 per cent. of the whole course, is only 725 feet, or an average of less than 3 feet per mile. The descent is accomplished without abrupt pitches, and even with few rapids having fall of much consequence. Between Olean and the mouth of the Kiskiminetas, 30 miles above Pittsburgh, the greatest amount of natural fall on any ripple of less than 1,000 feet length is 3.9 feet in 850 feet, at Patterson's falls, 29½ miles below the mouth of French creek; and upon longer ripples the largest total fall is 11.23 feet in 6,900 feet, at McGinnis' rapids, about a mile below Patterson's falls.(*b*) This river, in fact, presents the unusual feature of having a greater general slope in its middle and lower, than in its upper course. The section above Olean was described by lumbermen as sluggish far above toward the source, and in the first 25 or 30 miles above, the elevations obtained indicate an average slope not probably much, if at all, exceeding 1.5 foot per mile. In the succeeding 23 miles below Olean to

a See *House Ex. Doc. No.* 21, *Forty-fifth Congress, third session*, and *Senate Ex. Doc. No.* 89, *Forty-sixth Congress, second session.*
b Roberts' reports of surveys.

Salamanca the mean descent is about 1.8 foot per mile, thence to Corydon 4 feet per mile, and from Corydon to Warren 4.7 feet per mile; from Warren toward the mouth the rate of descent gradually diminishes, yet remains in general greater than for the section above Salamanca.

Table showing the fall in the Allegheny river.

Locality.	Distance from mouth of river.	Elevation of water-surface above mean sea-level.	Fall between points.	Distance between points.	Fall per mile between points.	Authority and remarks.
	Miles.	*Feet.*	*Feet.*	*Miles.*	*Feet.*	
Port Allegheny	*a* 283.00	*b* 1,482.00				
			57.68–	28.10	2.00–	Elevation on Buffalo, New York, and Philadelphia railroad, as given in report upon *Levels above Tide, Second Geological Survey of Pennsylvania.*
Olean	254.90	1,424.32				
			42.83	23.11	1.85	In the report by Mr. Thomas P. Roberts, United States assistant engineer, the elevation at Olean is given as 1,407.98 feet, having been taken from the list of elevations prepared in connection with the Pennsylvania geological survey. According to the profiles of the New York State canals, however, the elevation is 1,422.25 feet + mean low tide at Albany, which altitude has here been adopted and referred to mean ocean-level in New York harbor by adding 2.07 feet, the difference given at the Coast Survey office.
Salamanca	231.79	1,381.49				
			92.72	23.13	4.01	
Crest of Corydon dam	208.66	1,288.77				
			98.77	21.06	4.69	
Warren suspension bridge	187.60	*c* 1,190.00				
			75.79	22.58	3.36	Elevations obtained, as at Olean, by adding 16.34 feet to the figures given by Mr. Roberts.
Head of Tidioute island	165.02	1,114.21				
			74.35	21.77	3.42	
Hemlock island	143.25	1,039.86				
			61.80	20.35	3.04	
Franklin, mouth of French creek	122.90	978.06				
			278.86	122.90	2.27	
Pittsburgh, mouth of Allegheny river	0.00	699.20				Low-water surface in river (see *Elevations of Datum Points*, as obtained by Mr. James T. Gardner for the *Geological Survey of the Territories*).

a Portion above Olean obtained by map measurement. *b* In this case elevation of rails above tide. *c* Estimated.

In that portion of its course lying north of the Pennsylvania boundary the river is bordered by wide bottom-lands, varying from half a mile to two or three times that distance in breadth between the hills, and in places, as in the vicinity of Olean, subject to partial overflow during freshets. At Corydon and below the valley becomes more contracted, and at times the hills rise with steep slopes directly from the water. The bed in this upper portion is mainly gravel. From Olean to Jamison's falls, a few miles below Salamanca, it is almost exclusively composed of this material or of gravel and sand. At Jamison's falls loose rocks appear in the stream, and at Limestone falls, 13 or 14 miles below, and within a few miles of the New York and Pennsylvania boundary, the bed is underlaid by solid limestone rock, and there is a descent in the water-surface of 3.84 feet in 650 feet. Thence down stream loose rocks become abundant, and are usually to be found at the shoals, more or less completely embedded in the gravel.

The country drained by the upper course of the Allegheny is said to be quite well supplied with springs, the waters of the river are clear, and are tolerably well sustained in volume, considering that there are no artificial reservoirs and no lakes or swamp-lands of importance to regulate the flow. The natural result to be expected from the clearing of the timber and the settlement of the country is being realized, however, and the discharge appears to be growing more variable and unreliable than formerly. The lowest pitch is commonly reached in the early part of September, but there are few data to show the actual volume of water flowing in low stages. Mr. Roberts, in his report upon the reconnaissance of the lower river, made in 1878, states that he gauged the discharge at a ripple 19.2 miles below French creek and found it to be 143,900 cubic feet per minute, or say 2,400 cubic feet per second. The river was at that time about 3 inches above its lowest stage, in falling to which it was estimated that the discharge might be reduced by as much as 20,000 cubic feet per minute, or 330 per second. Mr. Roberts also mentions that the volume of the river near Pittsburgh is said to sink as low as to 80,000 cubic feet per minute, or 1,330 per second, in the lowest stages, but expresses the opinion that more exact measurements would perhaps show a closer agreement than exists between the data here given. These results may be thus presented:

Data concerning the discharge of the Allegheny river.

Locality.	Stage of water.	Drainage area.	Flow per second.	Flow per second per square mile.	Remarks.
		Sq. miles.	*Cubic feet.*	*Cubic feet.*	
Roberts' Run ripple, 19.2 miles below French creek.	Three inches above lowest water marks.	6,020	2,400	0.40	Gauging made in 1878 by Thomas P. Roberts, United States assistant engineer.
Do	Lowest water		2,070	0.34	Roughly estimated from the above gauging by Mr. Roberts.
Near Pittsburgh	do	11,100	1,330	0.12	Volume said to be reached at times.

The elevated region about the upper course of this river is often covered in winter by a very deep body of snow, which not infrequently attains a depth of 3 feet on a level in the more accessible districts, and not unlikely much more than that among the mountains. The melting of this mass of snow produces a heavy spring freshet, usually in March, and other rises are also caused by the rains of early summer and of autumn. These freshets affect the river in a varying manner, according to the conditions existing in different parts of its course.. Thus, in the comparatively sluggish portion above Salamanca, the stream is described as rising gradually, attaining in the vicinity of Olean usually a height of about 10 feet above low water and submerging the flats to depths of from 1 to 5 feet. The highest rise of which any thing could be learned was that of 1865, reported to have been between 21 and 22 feet at Portville, a few miles above Olean, and at the latter point there was a rise of 15.8 feet in 1873. As the river here rises rather slowly, so it also runs out slowly, a high stage of water sometimes holding for two weeks and stopping the mills near Olean. Farther down stream, on the other hand, the river is regarded as rising and falling quite rapidly, and along the section on which Corydon is situated, where the slope is twice as great as above Salamanca, the valley lands are overflowed only at long intervals and during extremely high freshets.

Ice is a powerful and destructive agent on this river. It forms very thick, sometimes 30 inches at Franklin, and when forced out by a rise in the stream, meeting but few obstructions to reduce it to fine pieces, becomes gorged and piled up in bends and on shoals. Generally the ice-dams thus made soon go out, but large masses of cake-ice are left on the banks, to which they become firmly cemented; in some subsequent rise they float off, carrying with them gravel, large stones, and even sometimes, it is said, tearing out trees. Mr. Roberts states that "at Kinzua, in the upper wide bottom-land region, 54½ miles below Olean, an ice-gorge some years ago dammed the river up, and caused it to flow in a circuitous route a mile or more through the bottoms, where it washed off the soil of cultivated fields and caused much damage to property before finally returning to the channel". It is evident that such heavy ice-runs must be a menace to dams scattered along the river, yet they are maintained in security at a number of points, and every additional one tends to mitigate the evil.

Water-power is employed on the Allegheny river at Corydon, Salamanca, Portville, and at several scattered points above, its use being confined mainly to saw-mills. The number of these mills along the river was formerly greater than now, but has decreased with the clearing away of much of the timber, although there has at the same time been an increase in the size of those concerns continuing operations. Although it is not probable that the power of the river could now be developed and profitably utilized to much extent for sawing lumber, yet the location of its course seems very well suited to the manufacture of wood-pulp, paper, and various articles of wooden ware. Wood-pulp is now manufactured at Salamanca and Corydon by water-power; at the latter place the material employed is principally poplar and basswood, of which there is said to be an abundance in the vicinity. At each of the three points which have been mentioned in particular as sites where power is utilized, the dams are low structures, built of piles, which is indeed said to be the prevailing construction on the streams of this section.

The extent of utilization of the extreme upper river may sufficiently well be learned from the table of utilized power; personal examinations were carried but a few miles above Olean, New York. At that place the stream is about 200 feet wide, shallow, with a moderate current and gravelly bed. The banks are perhaps 10 feet high, succeeded to the south or left at a short distance by hills, while on the north side there stretches out a wide level valley, in which the village is built. A few miles up stream, at a point locally known as Weston's Mills, in the town of Portville, the firm of Weston Brothers has a large saw-mill, and a second, 3 miles still above, at Mill Grove. At the latter point a fall of about 5½ feet is obtained, and a gang-saw, a "slabber", and a circular saw are run, from 5,000,000 to 6,000,000 feet of hemlock lumber being sawed annually. The supply of this variety of timber is large, and it is being felled all the way from Olean to the head of the river; accessible supplies of pine, however, along the course are very limited, and the Westons are the only firm cutting that kind of timber, though formerly lumbering operations were confined to it almost exclusively. At the lower mill the sawing is about half in pine and half in hemlock, and amounts, on the average, to about 12,000,000 feet per annum, ranging from 10,000,000 up to 17,000,000. Steam-power is used in a planing-mill, a shingle-mill, and some other works, but substantially all the sawing is done by water-power, and there are operated 2 flat gang-saws, 2 "slabbing gangs", 2 "English mills", and other machinery. The fall is about 5½ feet, never exceeding 6, and it is estimated that not far from 250 horse-power is employed. The mill is run throughout the year, and both night and day when the water-supply is sufficient. This is the case for from six to nine months in the year, but for the remainder of the time there is more or less shortage. During the dry season of 1882, for some months it was possible to run only about one-half the works, and that for but twelve hours per day. The storage is sufficiently large, extending back 3 miles at the lower privilege and 10 miles at the upper, to control at such times the flow of the stream, the night-water just about filling the lower pond. The dam is 220 feet long and not over 5 feet high. It consists of piles ranged across the stream in three rows 8 feet apart. On the tops of the piles are capping-pieces, and, over all, planking, giving a single slope, and that down stream. The front and back of the dam are vertical and faced with planking, the planks running horizontally; the facing of the back is carried down probably 5 feet into the river-bed, which is composed of gravel; that of the front (fastened to the inner surfaces of the piles) extends only to the bed. The interior of the structure is filled in with loose stone.

The next use of power is met with at Salamanca, between 25 and 30 miles farther down stream. The river still maintains a gravelly bed and runs shallow, but has increased in width to from 300 to 350 feet and is confined between banks of fair height. The village has 2,500 inhabitants, and lies on the right bank, in a valley not apparently more than half or three-quarters of a mile wide, and shut in by high, partially-wooded hills. The dam is somewhat convex up stream, and runs out in two sections to an island, with a total length of about 415 feet. It is a pile structure, similar in construction to that already described, but with a slope each way from the crest. The front slope is 16 feet long and covered with 3-inch planking; it decreases in height above the river-bed from 7½ feet at the crest to 3 feet at the overfall, and serves as an apron. The back slope is continued down to or into the river-bed, and near the foot the space beneath is filled in with brush and stone; otherwise the space under the covering of the dam remains open. There are five rows of piling, about 6 feet apart in the direction of the stream, and penetrating probably an equal distance into the bed, one row beneath the crest and two on each side; transversely to the stream the piles are driven at intervals of about 8 feet, and crib-work abutments protect the ends of the structure. This dam was erected at a cost stated to have been $3,000; it stands securely and is reasonably tight.

A race about 75 feet wide leads down the south bank perhaps a third of a mile to the mills owned by Messrs. Hall & Whitmore. A fall averaging say 7 feet, with a maximum of about 8, is obtained, and an estimated total of 200 horse-power is employed in works for the manufacture of lumber and wood-pulp. Fifteen tons of pulp are ground per week, and are shipped to Rochester, Cleveland, and other points. The saw-mill has a capacity of 100,000 feet per 24 hours, and actually manufactures from 5,000,000 to 6,000,000 feet of lumber yearly; one gang of 26 saws, one circular saw of 6 feet diameter, three planers, and a lath-mill are run, besides other small machinery. Pine timber is obtained 10 miles above Bradford, Pennsylvania, and hemlock at various points. Pine has hitherto been the principal variety sawed, but here, as elsewhere, will soon be entirely supplanted by hemlock. The supply of water suffices for the present demands of the works for about eight months in the year. An occasional stoppage of the mills is forced in winter by anchor-ice, here known as slush-ice, and more or less trouble is also experienced for three or four weeks during the year from the backwater resulting from freshets.

Estimate of power at Salamanca.

Stage of river.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		Effective horse-power of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.					
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	*1 foot fall.*	*7 feet fall.*	
Low water, dry year	9	11½	10	9½	40	1,556	250	28.40	200	200±
Low water, average year							320	36.35	250	
Available 10 months, average year							500	56.80	400	

The Buffalo, Pittsburgh, and Western railroad follows down the river from Salamanca to Oil City, crossing several times. For 40 miles above the New York and Pennsylvania boundary the land adjoining the river for half a mile in width on each side belongs to the Seneca Indian reservation; below the boundary, in Pennsylvania, a strip 2 miles long and half a mile wide, lying on the right bank of the river in the vicinity of Corydon, is included similarly in the Cornplanter reservation. On these reservations the Indians are said to live in a poor, shiftless fashion, doing but little to improve their lands and engaging in no manufacturing industry whatever.

From Salamanca to Corydon ripples appear here and there in the stream, the bed continues gravelly, and one bank or the other is often low. At Corydon the valley is similar to what has been described at points above, though somewhat narrower. The lands adjacent to the river are here seldom overflowed and are very valuable for farming, being finely suited to the raising of grass and the various grains. Beyond rise high hills, frequently with steep slopes; these are wooded, but most of the larger timber has been cut away from the immediate valley sides. The settlement in this section is very sparse, and the entire township of Corydon contained in 1880 but 335 inhabitants. At the village of the same name the river is obstructed by a low dam not over 4 feet high, built about the year 1865 at a cost estimated not to have exceeded $4,000. The main structure is about 350 feet in length, and, like the dams farther up the river, is built of piles, running across the river in this case in four rows 8 feet apart; the cross-section is similar to that of the dam at Salamanca, except that there is one less row of piles. With 1-foot flash-boards, or "brackets", as they are also called, a fall of about 6 feet is obtained at the mills, which are on either side of the river. On the west bank are Leach's saw-mill, not running at the time it was visited, and Dalrymple's mill, at which probably 1,000,000 feet of lumber—pine and hemlock—is sawed yearly. On the east bank power is used as follows: By Sunderlin & Payne for a saw-mill and for the manufacture of fork-, hoe-, rake-, and broom-handles and dowels, the firm running 6 circular saws, varying from 12 inches to 5½ feet in diameter, and using about 1,000,000 feet of lumber yearly, largely maple and ash; by the Jamestown Wood Pulp & Paper Company, having an average daily production of about 1½ ton; by F. J. Morrison for a saw-mill at which probably 1,500,000 feet of umber is sawed annually; and by Messrs. F. J. & P. Williams for a shingle-mill with an estimated capacity for

manufacturing 1,500,000 shingles per year. Spokes, hubs, and staves are also largely manufactured in the village, though not by water-power. The power at the privilege described is sufficient for the full supply of the mills grouped around it for only about four months in the year. The volume of water carries ice clear of the dam, and very little hinderance is suffered from backwater.

Estimate of power at Corydon.

Stage of river.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		Effective horse-power of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.					
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	1 *foot fall.*	6 *feet fall.*	
Low water, dry year	9	11½	10	9½	40	1,814	290	32.94	200	350±
Low water, average year							380	43.17	260	
Available 10 months, average year							580	65.89	400	

There are thought to be other sites on this section of the river as available for improvement as the one described, A few miles below the village a part of the river is said to be controlled by a dam running out from one bank to an island, but the use of power is unimportant, and no other developed privilege below Corydon was reported. From that point down to Kinzua, at the mouth of Kinzua creek, the valley is narrow, apparently seldom more than a quarter or a third of a mile wide, and though much of the way the river runs near the hills, yet at least one bank is usually low. There is a fair current, with occasional ripples and islands. Just below Kinzua the hills shut in, and at points rise steep and wooded directly from the river. The valley continues contracted, the flats narrow and disconnected, until, at Warren, there is again a widening. This place is prettily situated on the left bank, on a level terrace stretching back a short distance to the hills.

In the following table is given a list of those ripples between Olean and Warren on which the fall is not less than 3 feet. The river below Warren being navigable, though only for a small portion of the year to that point, and its improvement for navigation, at a moderate outlay, being considered practicable, that section will not here be assumed as available for water-power:

Estimate of power at the principal ripples on the Allegheny river between Olean and Warren.(a)

Locality.	Drainage area.	Distance above Warren.(b)	Length of ripple.	Fall on ripple.	Theoretical horse-power per foot of fall, based on average flow for the 24 hours.		
					Low water, dry year.	Low water, average year.	Available 10 months, average year.
	Sq. miles.	*Miles.*	*Feet.*	*Feet.*			
Ripple below Salamanca	1,556	43.2	1,200	3.32	28	36	57
Sunfish	1,670	37.1	1,050	3.03	31	40	61
Gravel bars	1,746	28.1	800	3.37	32	41	64
Limestone falls	1,784	25.4	650	3.84	33	43	66
Corydon (dam and ripple)	1,814	20.8	600	6.31	33	43	66
Gilman's bar	1,872	16.1	500	3.02	34	44	68
Harrison's lower ripple	1,923	13.3	800	3.42	35	45	70

a List of ripples taken from reports of surveys by Thomas P. Roberts, United States assistant engineer.
b For distance above Pittsburgh add 187.7 miles.

TRIBUTARIES OF THE ALLEGHENY RIVER.

The principal affluents of the Allegheny river, as regards extent of drainage area, are the Conewango and French creeks on the west side, and the Clarion and Kiskiminetas rivers on the east. Aside from the main river, the examinations made in this section were confined to the two first-mentioned tributaries. Some information concerning the Clarion and Kiskiminetas is contained in the report, already referred to, of a reconnaissance of the lower Allegheny, from which it appears that in a dry season those streams, in common generally with the tributaries entering the main river from the east, are very poorly sustained in volume, and in that respect are unfavorable to use for water-power. Thus, at the time of his examination, made in October, 1878, Mr. Roberts roughly estimated the discharge of the Clarion river during the low stage then prevailing to be not more than one-twentieth that of French creek, though its drainage basin is greater by some 50 square miles. The Kiskiminetas also was found very low, its discharge being estimated as less than 90 cubic feet per second, or about an eighth that of French creek at the same period; yet the former drains 1,800 square miles and the latter only about 1,130.

Drainage areas of tributaries of the Allegheny river.

Stream.	Square miles.	Stream.	Square miles.
Oswayo creek	245	French creek	1,130
Olean creek	156	Clarion river	1,184
Great Forks creek	139	Red Bank creek	546
Tunegawant creek	178	Mahoning creek	394
Conewango creek	896	Crooked creek	265
Tionesta creek	446	Kiskiminetas river	1,799
Oil creek	299		

Table of altitudes on various tributaries of the Allegheny river.

Stream.	Locality.	Distance from mouth of stream.	Elevation above tide or above ocean-level.	Remarks.
		Miles.	*Feet.*	
Olean creek	Hindsdale, New York	8.5	1,456	Elevation of rails at station above tide, corrected from levels of Buffalo, New York, and Philadelphia railroad.
Do	Mouth	0.0	1,424	Water-surface above mean ocean-level.
Great Forks creek	Ellicottsville, New York	11.0	1,548	Water-surface in Great Valley creek above ocean-level, by profile of Rochester and State Line railroad.
Do	Mouth	0.0	1,389	Water-surface above mean ocean-level.
Tunegawant creek	Bradford, Pennsylvania	10.5	1,444	Rails at station above ocean-level, corrected from Finch's profile, Bradford branch of New York and Erie railroad.
Do	Mouth	0.0	1,400	Water-surface above mean ocean-level.
Tionesta creek	Sheffield	37.0	1,337	Rails at station referred to mean tide at Baltimore, corrected from levels of Philadelphia and Erie railroad.
Do	Mouth	0.0	1,061	Water-surface above mean ocean-level.
Oil creek	Titusville	16.5	1,194	Rails at station above mean ocean-level, by profile of Pittsburgh, Titusville, and Buffalo railroad.
Do	Mouth	0.0	1,002	Water-surface above mean ocean-level.
French creek	Lebœuf	58.2	1,217	Rails at station referred to mean tide at Baltimore, corrected from levels or Philadelphia and Erie railroad.
Do	Meadville	26.0	1,080	Rails at station above ocean-level, by profile of Atlantic and Great Western railroad.
Do	Mouth	0.0	978	Water-surface above mean ocean-level.
Clarion river	Ridgway	73.5	1,393	Rails at station referred to mean tide at Baltimore, corrected from levels of Philadelphia and Erie railroad.
Do	Mouth	0.0	871±	Water-surface above mean ocean-level.
Red Bank creek	Brookville	40.7	1,235	Rails at station referred to ocean-level, by levels of Bennett's Branch railroad.
Do	Mouth	0.0	830±	Water-surface above mean ocean-level.
Kiskiminetas river	Johnstown on the Conemaugh	64.0	1,184	Rails at station above mean ocean-level, by Pennsylvania Railroad levels.
Do	Blairsville	37.5	965	Rails at Pennsylvania canal above mean ocean-level, by Pennsylvania Railroad levels.
Do	Mouth	0.0	754±	Water-surface above mean ocean-level.

NOTE.—The above table does not furnish the actual fall in the water-surfaces of the various streams, and is simply intended to convey a rough idea of the descent along their courses. The distances given are only approximate, having been obtained by map measurement to a not very large scale. The elevations above the mouths have been taken from the report on *Levels above Tide, Second Geological Survey of Pennsylvania.* The elevations of water-surface at the mouths have been estimated as nearly as possible from the results of surveys by Mr. Thomas P. Roberts, as given in his reports, correcting those results, however, to agree with the elevations adopted for the New York state canals; the correction which has been applied consists in adding 16.34 feet, as already explained in connection with the table of altitudes for the main Allegheny river. Below Franklin the elevations at the mouths of the tributaries have been obtained by subtracting from the assumed elevation at the mouth of French creek the fall as shown by surveys of the Allegheny Valley railroad, stated by Mr. Roberts in his report of December, 1878 (*House Ex. Doc. No.* 21, *Forty-fifth Congress, third session*).

Conewango creek.—The source of this stream is in the northeastern part of Chautauqua county, New York, within 10 miles of lake Erie; thence the course is irregular, but on the whole southerly, into Warren county, Pennsylvania, and at the borough of Warren a junction is effected with the Allegheny river. By general course the length of the stream is 45 or 50 miles. There are dams at various points along its course, but the chief manufacturing point within the section drained is Jamestown, a very attractive and enterprising village of between 9,000 and 10,000 inhabitants, about 3 miles from the foot of Chautauqua lake. The outlet of this lake runs easterly through the town of Ellicott, and having been joined by Cassadaga creek continues into the town of Poland, where it joins the Conewango.

Chautauqua lake lies near the center of the county bearing the same name, its head within 8 miles of lake Erie. It occupies a long and deep depression among the surrounding hills, which rise 600 or 800 feet above its level. The length of the lake is 16 or 18 miles; in width it varies, in general, from 1 to 2 miles, but near the center becomes so contracted as to receive the appearance of two separate lakes joined by a narrow arm. As represented on French's map of New York state, its surface covers an area of about 18.4 square miles, and in the *Gazetteer of New York* its elevation above tide is stated as 1,291 feet. Assuming the corresponding elevation at the mouth

of Conewango creek to be 1,190 feet,(*a*) there is a fall to that point from the lake of 101 feet in a distance, following the windings of the stream as accurately as practicable on the map, of about 34½ miles; the average descent for the entire distance is therefore not far from 3 feet to the mile.

The main employment of the outlet for water-power is at Jamestown, the manufactures of which are quite extensive in shoes, chairs, worsteds, cottons, alpacas, and other goods, but are largely based upon steam as motive power. The stream is there perhaps 50 feet wide, and in the upper part of the village is obstructed by a dam by means of which a partial control is exercised over the storage of the lake. There is a tributary area above that point, including the surface of the lake itself, of 178 square miles, but the restrictions are such that the drainage passing down through the outlet can not be maintained at a uniform rate of flow during the year, but at certain times there is a considerable wastage over the dam, and at others the supply of water runs short at the mills. Numerous springs assist in feeding the lake, and the rains and melting snows of spring regularly fill it and cause a surplus of water for the demands of the mills at Jamestown. From spring on through the dry season the volume is steadily reduced, the range in level during the year being stated as ordinarily 3 feet, or from 1 foot above the crest of the upper dam to 2 feet below. Occasionally a strong wind up the lake will almost entirely cut off the discharge through the outlet. The lake is navigable, and is thus largely utilized in summer, both by pleasure steamers and for the transportation of freight to and fro between Jamestown and Maysville, at the head, where connection is had with the Lake Shore and Michigan Southern railway by a short intervening line. Near the foot of the lake the depth is shallow, and the interests of navigation forbid the lowering of the water-surface to any considerable extent; and, on the other hand, it has been decided in court that the surface must not be artificially maintained at a higher level than under the present arrangement.

From the upper dam a race follows down the left bank of the outlet, giving at the lower mill a fall of about 11 feet, and supplying power to two grist-mills and to half a dozen or so other establishments, comprising in their production machine- and foundery-work, axes, washing-machines, planters, chairs, sashes, doors, blinds, and other articles. D. H. Grandin has a first right to sufficient water for use in his grist-mill, and estimates that about 125 horse-power of water-wheels is there employed under a fall of 11 feet. For about one-half the year the supply of water is equal to the requirements of the various mills on the race, but during the rest of the time, and especially in the months of July, August, and September, most of them are compelled to rely in large part upon steam. With all the other concerns shut down there is at times not enough water for the five wheels at Grandin's mill, and when there is an unfavorable wind on the lake there is even for a day or two at a time an insufficient amount for a single wheel.

In the lower part of the village the outlet is again dammed, and a fall of 6 feet is obtained, furnishing power to Allen, Preston & Co.'s woolen-mill, to John T. Wilson's saw-mill, lath-mill, and sash-and-blind factory, and to the Breed Furniture Company's works; some waste water is also used in a stave factory.

Still farther down in Jamestown, at a place locally known as Dexterville, another privilege is in use, with an extreme fall stated as 16 feet. About this point are grouped a grist-mill, a saw-mill, and works for the manufacture of axes and edge-tools.

Drainage areas.

	Square miles.
Chautauqua outlet at foot of lake	178
Chautauqua outlet below Cassadaga creek	343
Conewango creek at mouth	896

French creek.—Heading in the extreme southwestern corner of New York state, in Chautauqua county, its sources within a dozen miles of lake Erie, French creek, or, as it was once called, the Venango river, enters Pennsylvania, and making a bold curve to the westward through the counties of Erie and Crawford, swerves around to the southeast, cuts across a corner of Mercer, and near the center of Venango county joins the Allegheny. The area of its drainage basin has already been given as 1,130 square miles. Its entire length is by general course 75 miles, or, following the bends closely by map measurement, 90 miles; but portions of the stream are very crooked, and the actual distance by water from source to mouth is doubtless considerably greater.

The country drained has a moderately rolling surface, and was formerly covered with a heavy growth of timber, which was cut and rafted down the stream. The supply of pine has now become greatly reduced, and comparatively little rafting is done. For that which is still carried on advantage is taken of the high stages of water prevailing in spring, early summer, and fall. There is an important rise in the spring, largely due to melting snows, and another in June, caused by heavy rains; after the latter freshet no rafting is done until the water is again raised by autumn rains. Many years ago the stream was very gradual in its fluctuations, rising slowly and remaining up for a long time. Within the course of fifty years, however, there has been a noticeable change in this respect, and with the clearing of the country the oscillations have come to take place more rapidly, though even now the stream appears by no means to be what may be termed "flashy". At the mouth it is stated that after a general rain the stream continues rising for about twenty-four hours beyond the cessation of the storm. The bed is in general gravelly, though at the mouth composed of a soft rock which slakes on exposure to the air. The banks are much of the way

a See elevation at Warren, table showing the fall in the Allegheny river, page 10.

of black loam, and though of fair height are often unequal, being on the one hand low and succeeded by flats, while on the other they rise to bluffs. They are not so high but that in many localities they are submerged during extreme freshets, and in some places during ordinary ones. The common spring rise at Meadville is stated to be in the neighborhood of 11 feet, but at times the stream has been known to run a mile wide, stretching from hill to hill. Springs are said to be freely scattered over the drainage basin, and the low-water volume of the stream is fairly well sustained. West of Meadville there is a lake of considerable size, and also in the upper waters there are one or two small tributary lakes.

Table showing the fall in French creek.

Locality.	Distance from mouth.	Elevation of water-surface above mean sea-level.	Fall between points.	Distance between points.	Fall per mile between points.	Authority for elevations.
	Miles. (*a*)	*Feet.*	*Feet.*	*Miles.*	*Feet.*	
Crossing of New York, Pennsylvania, and Ohio railroad a short distance east of Cambridge.	42.7	1,128	70	20.0	3.5	Elevations kindly furnished by Mr. Charles Latimer, chief engineer of the New York, Pennsylvania, and Ohio railroad.
Crossing by above railroad a few miles below Meadville.	22.7	1,058	80	22.7	3.5	
Mouth of creek	0.0	978				See table of fall in Allegheny river.

a By map measurement.

The section tributary to French creek is finely suited to farming, and has a large production of wheat, wool, butter, and cheese, and many cattle are raised. Although most of the pine timber has been cut, much hard wood yet remains standing in the upper basin. In the region about Meadville the soil on the hills is clayey, while in the valleys there is a rich black loam. Toward the mouth the land is described as finely adapted to wheat-raising, but poorly farmed; the production of wheat is thought to be steadily increasing, however, throughout this part of the state. On the main portion of the stream the principal places are Franklin, directly at the mouth, with a population of 5,000; and Meadville, some 30 miles above, with 8,900. In addition to the use of the stream for floating rafts, there is a small amount of navigation by flat-boats, these and the rafts passing down over the dams in long sloping chutes, from which water is at other times excluded by a log placed across at the head. Years ago Meadville enjoyed communication, via the Erie canal of Pennsylvania, both with the Ohio river at Beaver and with lake Erie at Erie. From a point 2 miles above the city, a canal opened out from French creek, and following down through and for about 7 miles below Meadville on the east bank, then crossed the stream on an aqueduct, and passing westwardly along the valley of Conneaut outlet reached Conneaut lake, on the summit between French creek and the Beaver river. This lake, which when full covered 2,600 acres, was artificially raised by an embankment and served as a storage reservoir, feeding the main canal both northerly down the Conneaut Creek valley toward lake Erie, for 45½ miles, and southerly for 15½ miles down the Shenango line toward the Ohio river. The canal was long since abandoned, but the lake of course remains as such, though it is thought to be lower than it was when in use for storage. It lies in a marshy district which is being successfully drained. The greater portion of French creek is followed closely by the New York, Pennsylvania, and Ohio railroad—below Meadville by its Franklin branch, and above by the main line.

Measurements of the volume of water flowing in this stream were made once or twice previously to 1839, also during that year, and again in 1867, the results of each being recorded in a report made in December, 1867, by the late W. Milnor Roberts, at that time consulting engineer to the Erie Canal Company of Pennsylvania. These measurements were made in the vicinity of Meadville, and in October, 1878, a rough gauging was made at the mouth of the stream by Mr. Thomas P. Roberts, then engaged in a reconnaissance of the Allegheny. The volumes of flow found by these various gaugings, together with some additional data, are contained in the following table:

Data concerning the flow of French creek.

Locality of gauging.	Date of gauging.	Stage of water.	Drainage area.	Flow per second.	Flow per second per square mile.	Remarks.
			Square miles.	*Cubic feet.*	*Cubic feet.*	
Above Meadville (*a*)	Previously to 1839.	Stated as minimum flow of extreme low water.	618	138	0.22	Gauging by Alonzo Livermore, civil engineer.
Do	do	do	618	159	0.26	Gauging at another time by Major Douglass, civil engineer.
Site of feeder-dam, 2 miles above Meadville.	September, 1839	Unusually low, but not extreme low water.	618	380	0.61	Gauging under direction of W. Milnor Roberts.
Do	October, 1867	Minimum flow at driest part of an unusually dry season.	618	222	0.36	Gauging made by H. H. Loveridge, under direction of W. Milnor Roberts.
Mouth of stream	October, 1878	Not stated, but the Allegheny was about 5 inches above its lowest stage, and during the month its principal tributaries were found very low.	1,130	708	0.63	Rough gauging made by Thomas P. Roberts, United States assistant engineer.

a Assumed to have been at feeder-dam, though not definitely so stated.

French creek was not examined above Meadville. There is said to be a paper-mill run by water-power 4 miles above the city, a flouring-mill at Saegerstown, another at Venango, and probably more or less use of power at other points farther up the course. At Meadville the stream runs about 175 feet wide, and on the right or west side approaches close to the high hills which inclose the valley; on the east side is a broad level plateau, on which the city lies, and beyond a rise to hills. The power of the stream is here put to use for the city water-works, and for a flouring-mill carrying 5 runs of stones and some rollers. Advantage has been taken of the old state improvements, water being brought some 2 miles from the feeder-dam in the channel of the canal which has already been mentioned. The total fall which could be obtained with the present height of dam and length of canal is stated as 21 feet; the fall actually in use ranges from 16 to 18 feet. The water-works have a single wheel, rated at about 110 horse-power, and the flouring-mill has 2 wheels, also estimated to give in the aggreate a little over 100 horse-power, but at neither place is the full power commonly in use. The supply of water is always sufficient for the water-works alone, but in low water sometimes will not fill the demands of both these and the flouring-mill. The dam is some 400 feet long, with an entire width at base of 90 or 100 feet. Many years ago there was a dam at this site, but the overfalling water scoured a deep hole below it and the state built a new structure immediately below, filling the intervening space with stone. The present dam, or at least the newer portion, is a timber and stone crib-work covered with a double thickness of 4-inch planking. The fall from water-surface to water-surface is commonly about 10 feet, but in places the dam itself is thought to have a height, measured between foundation and crest, of as much as 25 feet.

Estimate of power at Meadville.

Stage of water.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.			Effective horse-power (rated) of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.						
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	1 *foot fall.*	17 *feet fall.*	21 *feet fall.*	
Low water, dry year							120	13.63	230	290	
Low water, average year	10	14½	9½	9	43	*a* 618	160	18.18	310	380	210±
Available 10 months, average year							240	27.26	460	570	

a At feeder-dam; drainage area at city, below Cussewago creek, is 720 square miles.

From Meadville to Franklin there was no power in use, so far as could be learned. In that distance there is a good current, with occasional ripples, and one or two considerable rapids, as at Carleton and near Franklin. For the whole section the average fall is probably not over 3 feet per mile. The valley is narrow, apparently seldom much exceeding a quarter of a mile in width between the bases of the hills, these growing higher and more abrupt toward the mouth of the stream. The course of the latter usually borders the hills on one side, but the opposite bank is low, and herein seems to lie, aside from the moderate fall, the principal objection to the development of power on this portion of the stream. There are doubtless some points where the banks would admit of a dam of fair height, but in general it may be said that any material raising of the water-surface would aggravate overflows above and endanger the railroad track, which, it is said, is even now sometimes submerged at points.

The last mill on the stream is at Franklin, but a short distance from the mouth. French creek has in this portion of its course a width ranging from 200 to 350 feet. In the valley-sides are outcropping horizontal strata of rock, which farther to the northward are not much exposed. Franklin is on the west bank, on a rather narrow plateau. Directly opposite, across French creek, there rises steeply a hill honeycombed with oil-wells and covered with a forest of derricks. Here, as at Meadville, the water-privilege has the benefit of an old state dam, built, in this case, some twenty-five or thirty years ago for the purpose of creating slack-water navigation. It is 325 feet long, and gives a fall of about 5½ feet; the construction is of timber and stone crib-work. The Venango flouring-mill, of which Messrs. Johnson & Co. are proprietors, carries 12 sets of rollers, and has a capacity for 100 or 125 barrels of flour per day. Six water-wheels are in use, estimated at 100 horse-power in the aggregate. Considerable leakage takes place through the dam; and for as much as one month in an ordinary year, and even two months in an unusually dry one, the mill has not a full supply of water. Freshet backwater from the Allegheny now and then causes a stoppage for a day or two, and ten years or so ago an ice-gorge a mile below in that river raised the water-surface in French creek above the crest of the dam, and for a month the mill could not be run.

Estimate of power at Franklin.

Stage of water.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		Effective horse-power (rated) of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.					
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	1 *foot fall.*	5½ *feet fall.*	
Low water, dry year							210	23.86	130	
Low water, average year	10	13½	10	9½	43	1,130	280	31.81	170	100
Available 10 months, average year							420	47.71	260	

Coal can, of course, conveniently and cheaply be obtained in this section. At Franklin the cost of "slack" coal (fine refuse from the mines, much used as fuel in generating steam) was stated to range ordinarily between $1 25 and $1 40 per ton, delivered, while it sometimes has reached as low figures as $10 or $12 per car-load. The price of coarse coal, by the car-load, was given as $2 50 per ton, delivered (December, 1882). Yet, notwithstanding the cheapness of fuel, the proprietors of the Venango mill were confident that, considering the cost of engineer and fireman, of coal, oil, insurance, and other items, they secured a more economical power from the river than they could from steam.

Table of utilized power on the Allegheny river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Allegheny river	Ohio river	Pennsylvania	Potter	Flouring and grist	2	18	52	.....	
Do	do	do	do	Saw	4	30	120	.....	
Do	do	do	McKean	do	2	6+	119	.....	
Do	do	do	do	Flouring and grist	1	7	30	.....	
Do	do	New York	Cattaraugus	Saw	2	11	350	.....	Town of Portville.
Do	do	do	do	Saw and pulp	1	8	200±	.....	Salamanca.
Do	do	Pennsylvania	Warren	Saw	4				
Do	do	do	do	Paper and pulp	1	6	350±	.....	Corydon privilege.
Do	do	do	do	Shingle	1				
Do	do	do	do	Wooden handles	1				
Oswayo creek and tributaries.	Allegheny river	do	Potter	Flouring and grist	4	21+	75	.....	
Do	do	do	do	Saw	9	58	260	.....	
Do	do	do	McKean	do	2	13	120	.....	
Do	do	New York	Allegany	do	1	6	30	.....	
Do	do	do	do	Flouring and grist	1	17	30	15	
Conewango creek	do	do	Chautauqua	Bee-hives	1	10	20	.....	Poland.
Do	do	do	do	Lumber, planed	1		20	.....	
Do	do	do	do	Flouring and grist	1		100	.....	
Do	do	do	do	Saw	1		40	.....	
Do	do	do	do	do	2	14	50	.....	
Do	do	do	do	Flouring and grist	2	15	43	.....	
Do	do	do	Cattaraugus	Saw	1	11	12	.....	
Do	do	Pennsylvania	Warren	Flouring and grist	1	6	40	.....	Warrenborough.
Do	do	do	do	Furniture	1		6	.....	
Do	do	do	do	Patent medicines and compounds.	1		5	5	
Do	do	do	do	Sashes, doors, and blinds	1		22	.....	
Do	do	do	do	Wheelwrighting	1		5	.....	
Do	do	do	do	Flouring and grist	1	6	20	.....	
Do	do	do	do	Saw	1	10	25	.....	
Do	do	do	do	Woolen	1	5	16	.....	
Cassadaga creek and sundry small tributaries.	Conewango creek	New York	Chautauqua	Flouring and grist	5	54½	125	30	
Do	do	do	do	Saw	2	13	55	.....	
Do	do	do	do	Butter and cheese	1	6	2	.....	
Chautauqua outlet	Cassadaga creek	do	do	Axes	1	Jamestown and vicinity—total fall at three privileges, about 33 feet.	.....	.....	
Do	do	do	do	Carpentering	1		15	.....	
Do	do	do	do	Cooperage	2		77	.....	
Do	do	do	do	Cutlery and edge-tools	1		175	80	
Do	do	do	do	Flouring and grist	5		398	30	
Do	do	do	do	Furniture	3		53	20	
Do	do	do	do	Lumber, planed	1		50	.....	
Do	do	do	do	Machinery	3		65	.....	
Do	do	do	do	Sashes, doors, and blinds	2		15+	.....	
Do	do	do	do	Saw	5		237	206	
Do	do	do	do	Staves	1		.....	.....	
Do	do	do	do	Wheelbarrows	1		45	.....	
Do	do	do	do	Washing-machines and clothes-wringers.	1		5	.....	
Do	do	do	do	Woolen	1		20	.....	
Sundry tributaries	Chautauqua lake	do	do	Flouring and grist	5	60	153	105	
Do	do	do	do	Saw	4	75	40	.....	
Do	Conewango creek	do	do	do	9	136½	168	45	
Do	do	do	do	Flouring and grist	3	45	106	15	
Do	do	do	Cattaraugus	do	1	18	20	.....	
Do	do	do	do	Saw	3	57	60	.....	
Do	do	do	do	Tannery	1	11	18	20	

Table of utilized power on the Allegheny river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Sundry tributaries	Conewango creek	Pennsylvania	Warren	Saw	1	22	20		
Kinzua creek	Allegheny river	do	McKean	Saw	3	19	46		
Do	do	do	Warren	Flouring and grist	1	7	15		
Broken Straw creek	do	New York	Chautauqua	Agricultural implements	1	9	22		
Do	do	do	do	Flouring and grist	3	34	142		
Do	do	do	do	Saw	1	9	10		
Do	do	Pennsylvania	Erie	Woolen	1	6	16		
Do	do	do	Warren	do	1	7	35		
Do	do	do	do	Wheelwrighting	1	11	8		
Do	do	do	do	Saw	7	64	173		
Do	do	do	do	Flouring and grist	4	27	108		
Tributaries	Broken Straw creek.	do	do	do	1	7	20		
Do	do	do	do	Saw	3	29	60	40	
Tionesta creek	Allegheny river	do	Forest	do	3	28½	165		
Do	do	do	do	Flouring and grist	1	12	60		
Do	do	do	Warren	Saw	2	15	24		
Do	do	do	do	Tannery	1		12		
Tributary	Tionesta creek	do	Forest	Saw	1	30	60	50	
Oil creek	Allegheny river	do	Crawford	Flouring and grist	4	35	222		
Do	do	do	do	Saw	7	82½	167		
Do	do	do	do	Wooden handles	1	5	23		
Tributaries	Oil creek	do	do	Flouring and grist	1	10	38	30	
Do	do	do	do	Saw	3	25	85		
Do	do	do	do	Woolen	1	8	15		
Do	do	do	Venango	Flouring and grist	1	16	25		
French creek	Allegheny river	New York	Chautauqua	do	2	20	56	15	
Do	do	do	do	Saw	2	15	37		
Do	do	Pennsylvania	Erie	Flouring and grist	4	35	162		
Do	do	do	do	Saw	8	89½	180	25	
Do	do	do	do	Sashes, doors, and blinds	1	7	6		
Do	do	do	Crawford	Flouring and grist	3	27	242		
Do	do	do	do	do	1	18½	100		Meadville.
Do	do	do	do	Pumping-works	1		110		
Do	do	do	do	Paper	1				
Do	do	do	do	Saw	1	5½	6		
Do	do	do	do	Woolen	1	5	20		
Do	do	do	Venango	Flouring and grist	1	5½	100		Franklin.
Tributaries	French creek	New York	Chautauqua	do	1	10½	27		
Do	do	Pennsylvania	Erie	Cooperage	1	9	18		
Do	do	do	do	Flouring and grist	2	18	70	25	
Do	do	do	do	Furniture	1	6½	8		
Do	do	do	do	Machinery	1	9	9		
Do	do	do	do	Saw	7	70+	148	30	
Do	do	do	do	Tannery	1	6	10		
Do	do	do	do	Wooden handles	1	10	31		
Do	do	do	Crawford	Flouring and grist	16	199	582	265	
Do	do	do	do	Iron castings	2	12	40	61	
Do	do	do	do	Saw	21	179½	407	35	
Do	do	do	do	Tanneries	2	23	20		
Do	do	do	do	Woolen	1	8	20		
Do	do	do	Mercer	Flouring and grist	1	20	20		
Do	do	do	Venango	do	5	61	125		
Do	do	do	do	Saw	2	19	35		
Do	do	do	do	Wheelwrighting	1	11	8		
Do	do	do	do	Woolen	1	16	6		
Clarion river	Allegheny river	do	Elk	Saw	4	38½	305		
Do	do	do	Jefferson	do	2	30	40	80	
Do	do	do	Forest	Saw	2	28	110	60	
Do	do	do	Clarion	do	4	57	110	40	
Do	do	do	do	Flouring and grist	2	6	38		
Tributaries	Clarion river	do	Elk	Saw	11	156	293		
Do	do	do	Jefferson	do	6	72	145		
Do	do	do	do	Flouring and grist	1	7	12		
Do	do	do	Forest	do	1	16	15		
Do	do	do	Clarion	do	21	335	516	47	
Do	do	do	do	Saw	7	78½+	116	45	

Table of utilized power on the Allegheny river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Tributaries	Clarion river	Pennsylvania	Clarion	Woolen	1	17	20		
Red Bank creek	Allegheny river	do	Jefferson	Flouring and grist	5	41	127		
Do	do	do	do	Saw	2	11½	62		
Do	do	do	Clarion	Flouring and grist	3	31	155		
Do	do	do	Armstrong	do	1	9	25		
Tributaries	Red Bank creek	do	Jefferson	do	6	77	152	100	
Do	do	do	do	Saw	11	110	297		
Do	do	do	do	Woolen	1	6	18		
Do	do	do	Clearfield	Flouring and grist	1	52	20	45	
Do	do	do	do	Saw	2	36	95		
Do	do	do	Clarion	Flouring and grist	2	22	30		
Mahoning river	Allegheny river	do	Indiana	do	7	49	285		
Do	do	do	do	Saw	1	11	50		
Do	do	do	Jefferson	do	3	23	150	52	
Do	do	do	do	Flouring and grist	7	60	208	20	
Do	do	do	Armstrong	do	3	17½	114		
Do	do	do	do	Saw	3	25½	120		
Tributaries	Mahoning river	do	do	do	1	15	20		
Do	do	do	do	Flouring and grist	1	24	15		
Do	do	do	Jefferson	Furniture	1	10	15		
Do	do	do	do	Saw	2	18	50		
Do	do	do	Indiana	do	4	27+	95		
Do	do	do	do	Flouring and grist	2	20½	75		
Do	do	do	Clearfield	do	1	30	20	35	
Do	do	do	do	Saw	5	167	135	30	
Kiskiminetas river	Allegheny river	do	Westmoreland	Flouring and grist	1	5	40		
Conemaugh river	Kiskiminetas river	do	do	do	2	28	28		
Do	do	do	do	Saw	1	10	6		
Do	do	do	Indiana	Flouring and grist	1	5	20		
Do	do	do	Cambria	do	4	39	66		
Do	do	do	do	Saw	7	91	130		
Small tributary	do	do	Westmoreland	Flouring and grist	1	14	15	25	
Loyalhanna creek and tributaries.	Conemaugh river	do	do	do	16	176	384	78	
Do	do	do	do	Woolen	1	15	10		
Other tributaries	do	do	do	do	5	65	66		
Do	do	do	do	Flouring and grist	5	99	105		
Do	do	do	Cambria	do	8	123	193		
Do	do	do	do	Saw	22	203+	404		
Do	do	do	do	Tannery	1	6	12		
Do	do	do	do	Woolen	1		15	40	
Do	do	do	Indiana	Flouring and grist	14	199½	357	55	
Do	do	do	do	Furniture	1	16	12		
Do	do	do	do	Saw	22	265+	456		
Do	do	do	do	Woolen	3	36	39		
Do	do	do	Somerset	Flouring and grist	23	338	455	84	
Do	do	do	do	Furniture	1	22	8		
Do	do	do	do	Saw	36	386+	651	30	
Do	do	do	do	Tannery	1	8	3		
Do	do	do	do	Woolen	2	26	24		
Sundry small streams	Allegheny river	do	Potter	Flouring and grist	1	24	48		
Do	do	do	do	Saw	1	20	30		
Do	do	do	McKean	Flouring and grist	2	12	50		
Do	do	do	do	High explosives	1	9	1		
Do	do	do	do	Sashes, doors, and blinds	1	4	12		
Do	do	do	do	Saw	6	114	218	65	
Do	do	New York	Allegany	do	2	52	65		
Do	do	do	do	Flouring and grist	2	28	49	20	
Do	do	do	Cattaraugus	Carriage and wagon materials.	1	17	16		
Do	do	do	do	Cooperage	1	18	15		
Do	do	do	do	Flouring and grist	9	109	310		
Do	do	do	do	Saw	29	335½	848	135	
Do	do	do	do	Woolen	1	7	10		
Do	do	do	Warren	Saw	9	104+	214	60	
Do	do	do	Forest	do	3	30	135		
Do	do	do	do	Flouring and grist	2	33	46		

Table of utilized power on the Allegheny river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Sundry small streams	Allegheny river	New York	Erie	Knitting	1	.....	20	.....	
Do	do	do	do	Cloth rolls and yarns	1	6	15	.....	
Do	do	do	do	Saw	2	14	27	.....	
Do	do	do	Mercer	Flouring and grist	2	27	40	.....	
Do	do	do	do	Woolen	2	19+	26	.....	
Do	do	do	Venango	Blacksmithing	1	.....	12	.....	
Do	do	do	do	Flouring and grist	10	92+	147	.....	
Do	do	do	do	Woolen	1	9	.....	.....	
Do	do	do	Clarion	Flouring and grist	3	52½	106	60	
Do	do	do	do	Saw	1	11	10	.....	
Do	do	do	Butler	Flouring and grist	6	91	145	125	
Do	do	Pennsylvania	Armstrong	do	18	277	410	309	
Do	do	do	do	Saw	3	34	55	.....	
Do	do	do	do	Woolen	1	9	10	.....	
Do	do	do	Indiana	Flouring and grist	6	66	119	108	
Do	do	do	do	Saw	3	.....	18	.....	
Do	do	do	Westmoreland	Flouring and grist	2	20	38	38	
Do	do	do	Allegheny	do	7	103½	151	120	

THE MONONGAHELA RIVER.

The main river is formed in Marion county, in the northern part of West Virginia, by the union of its West fork with the Tygart's Valley river. It then pursues a winding course to the northward for over 120 miles, entering Pennsylvania and joining the Allegheny river at Pittsburgh to make up the Ohio. The drainage basin comprises 7,625 square miles, against 11,107 for the Allegheny, and lies principally in the states already mentioned, though including also a small adjacent section of Maryland. The Monongahela drains part of the western slope of the Alleghany mountains, and the eastern portion of its basin, especially about the upper waters of the Cheat river, is extremely rugged, with little fertility. Passing to the westward across West Virginia, the country in time loses its strictly mountainous appearance, and though it continues elevated, presents extensive table-lands, not necessarily level, but, on the other hand, only moderately hilly and with rounded slopes. All this region was once heavily timbered, but has been quite thoroughly cleared except about the upper waters of the principal streams. Poplar is found well distributed; there is also much oak along the upper course of the West fork, and it is said that in the district tributary to the Cheat river there is considerable wild cherry, as well as spruce and hemlock. This upper portion of West Virginia is a blue-grass region, and is therefore splendidly suited to grazing. It yields largely in corn, but cattle-raising is the principal industry. Very little iron ore is found in the upper basin of the Monongahela, so far as ascertained, except toward its eastern border, but the variety of coal known as "Pittsburgh" occurs over the greater part, and in the vicinity of Fairmount, near the head of the main river, lies in four seams, of 11 feet, 5 feet, and two of 4 feet thickness, respectively.

Descending from the junction of the West fork with the Tygart's Valley river, the first use of water-power is found at Fairmount, an important village 3 miles below located on high bluffs on the left bank of the river. The latter is here crossed by a fine suspension bridge, and immediately under this is a low dam, not more than 4½ feet high, extending boldly up stream from each shore, and made up of four straight sections. The river-bed in this vicinity is mainly composed of sandstone ledge rock, coal-seams also occurring at points, and is covered more or less with gravel, and finer material in the pools. The dam is a crib-work of the following construction: Two sills cross the stream, resting on the bed; on the down-stream sill the face of the dam is carried up in say four courses of timbers, each course secured by binders—saplings of less diameter—running to the up-stream sill and firmly dovetailed to it. The face timbers break joints, and the binders do not come one above another, but are distributed irregularly. The whole structure is thoroughly bolted together, and all interstices are closely packed with loose rock. A fall of 4 or 4½ feet is obtained, and is utilized on the right bank at Springer & Barnes' 2-run flouring-mill. On the opposite bank there is also a small mill, not regularly run. Springer & Barnes count upon about eight months of good grinding at their mill during the year. The dam is not tight, and for two months or so in summer the mill is short of water, while for an equal length of time in winter the high stage of river prevents running on account of the backwater. The stream is about 450 feet wide at Fairmount, and is subject to great oscillations, having been known to rise, in extreme cases, 35 or 40 feet above the low-water surface below the dam.

Table showing the fall in the Monongahela river and its principal tributaries.

Stream and locality.	Distance from mouth. (*a*)	Elevation of low-water surface above mean sea-level.	Fall between points.	Distance between points.	Fall per mile between points.	Authority for elevations.
	Miles.	*Feet.*	*Feet.*	*Miles.*	*Feet.*	
Cheat river at Baltimore and Ohio Railroad crossing, Rowlsburg, West Virginia.	39	1,320	546	39	14.0	Baltimore and Ohio Railroad levels.
Cheat river at mouth	0	774				Estimated by adding to elevation at Pittsburgh 74½ feet, ascent to Virginia line, as determined by old survey. Now possibly altered somewhat by slack-water dams.
Tygart's Valley river at Baltimore and Ohio Railroad crossing, Grafton, West Virginia.	18	952	114	18	6.3	Baltimore and Ohio Railroad levels.
Tygart's Valley river at mouth	0	838				Do.
West fork of Monongahela river at Baltimore and Ohio Railroad crossing, Clarksburg, West Virginia.	25	890	52	25	2.1	Do.
West fork of Monongahela river at mouth	0	838				Do.
Youghiogheny river at Baltimore and Ohio Railroad crossing near Oakland, Maryland.	95	2,323	1,606	95	16.9	Do.
Youghiogheny river at Baltimore and Ohio Railroad crossing near Connellsville, Pennsylvania.	41	*b* 890				Do.
Youghiogheny river at mouth	0	717				Elevation roughly estimated.
Monongahela river at Baltimore and Ohio Railroad crossing 2 miles above Fairmount, West Virginia.	123	838	139	123	1.1	Baltimore and Ohio Railroad levels.
Monongahela river at mouth	0	699				Low water in Ohio river at Pittsburgh 699.2 feet above mean sea-level (see *Elevations of Datum Points*, by James T. Gardner, United States Geological Survey).

a Obtained by map measurement, and to be considered as approximate only. *b* Elevation of rails.

NOTE.—Elevations at points on the lines of the Baltimore and Ohio railroad were furnished through the kindness of Mr. James L. Randolph, consulting engineer of the company.

From Fairmount down to Morgantown, a distance of between 20 and 25 miles, the fall in the river is said to average slightly over a foot to the mile. The "Big falls" and "Little falls" indicated upon maps as occurring in this section, are described as not of any importance as regards amount of descent; at the former there is in low water an abrupt pitch of a foot or two, while the "Little falls" consist of rapids located in a sharp bend of the stream. Power is used at three points between Fairmount and Morgantown by small grist-mills obtaining their fall from low dams rudely built of loose stones.

Below Morgantown the river is not utilized for water-power in manufacturing at any point, with the single exception of the dam at Port Perry, near McKeesport, where there is a saw-mill turning out about 1,000,000 feet of lumber annually and employing 70 horse-power of wheels. In one sense navigation may be said to extend up the river to Fairmount, inasmuch as during high water steamers have occasionally ascended to that place. But the only regular navigation extends, or will soon extend, to Morgantown, 102 miles above the mouth, and is made possible by a series of dams creating slack-water. The first suggestion of an improvement of the navigation of the Monongahela by locks and dams is said to have been made in the report of a survey undertaken for the state by E. F. Gay, civil engineer, in 1828. Congress having declined the improvement of the river, by act of the state assembly of Pennsylvania, of March 31, 1836, "The Monongahela Navigation Company" was authorized to create slack-water navigation to the Virginia line and as much farther as the latter state might permit it to go. A survey was made in the summer of 1838 under W. Milnor Roberts, with the following results: From Pittsburgh to Brownsville the distance was found to be about 55½ miles, and the ascent a little over 33½ feet; from Brownsville to the Virginia line a little over 35 miles, with an ascent of 41 feet. The company constructed six dams, giving navigation to Jacob's creek, 84 miles from Pittsburgh. At a point above, known as Hoard's rocks, there was completed by the United States government, during the fiscal year ending June 30, 1880, a lock and dam creating slack-water to Morgantown. Two more dams were necessary in order to connect this navigation with that of the lower river—one at Jacob's creek, and a second between there and Hoard's rocks, at Laurel run. In 1880 Congress appropriated $25,000, and an equal amount in 1881, toward the necessary work at Laurel run, the second appropriation being on the condition that the navigation company should give proper assurance that it would construct the lock and dam at Jacob's creek. This assurance was given, and whenever the work shall have been finished there will be continuous navigation from Pittsburgh to Morgantown.

From Pittsburgh to McKeesport, some 15 miles, the Monongahela is lined at short intervals by extensive iron furnaces and mills. It runs through this section in a narrow valley, bluffs rising high on either side with varying abruptness. At some points there seems to be scarcely more than sufficient room left for the railroad which follows the east bank, while again the hills slope more gently, or recede from the water, leaving stretches perhaps a quarter of a mile wide of flat alluvial land which is under cultivation. Between the cities mentioned the navigation company has two of its dams, the rest being farther up the river. During much of the year there must evidently be a large

available power at these various dams, but the company has all the business in connection with navigation that it can attend to and does not wish to dispose of any water-power. None is now used except in operating the lock-gates, and, as we have seen, by a single saw-mill at Port Perry.

In view of the uncommonly dangerous character of this river as regards freshets and ice-runs, it may be of value to give a brief account of the navigation company's dams. They are numbered in order ascending from Pittsburgh, and have been thus described: (*a*)

The dams are constructed of logs, squaring at least a foot, built up perpendicularly from the bed of the river to near the water-level, when they begin to slope on both sides to the comb, after the manner of an old-time log cabin. They are tied together by cross-timbers parallel with the line of the river, bolted to the longitudinal timbers so as to form a network, with interstices of 7 by 9 feet, filled with stone. Their breadth at the base is about 65 feet; their depth below the slopes, as originally built, is from 3 to 6 feet, though, by reason of breaches, they are now much deeper in places.(*b*) Dams 1 and 2 run straight across the river. No. 3 is in three straight lines of unequal length—the middle one 280 feet, the other two aggregating about 420 feet—the middle one being at right angles with the channel, the others sloping from it downward to the shores, about 22 feet from the line of the middle part. Dam No. 4 is a segment of a circle—about 605 feet in length—and curves up stream, having a versed sine of 15 feet. Dams 5 and 6 are also segments of a circle, with the convex sides up stream, and are each about 600 feet long. These, by reason of their increased height, 13½ and 14 feet, have the longest slopes on the lower sides. The others slope about equally above and below—from 3 to 4 feet of slope to 1 foot of rise. They are sheeted above with double courses of oak plank, closely laid, 5 inches thick, spiked to the timbers, and covered with gravel. The sheeting below is of heavy oak timbers, or spars, flattened to 8 inches and spiked to the crib-timbers. The dams are further secured at their ends by high, strong cribs filled with stone, and above by double courses of heavy sheet-piles driven vertically into the bed of the river to such depth as to secure anchorage to the entire structure. In some cases, since their original construction, piles have been driven in below vertically, and above slopingly.

In spite of the strength of the dams on the Monongahela they have frequently suffered during the heavy freshets which sweep down the river. In 1843, dam No. 1 was badly injured; in April, 1852, there were two freshets, of seven days' duration each, which entirely submerged the works and carried away the office-houses at dams Nos. 2 and 3, and severely injured the locks; in May, 1856, about 200 feet of dam No. 2 was swept out; and in May, 1858, there was a greater flood than that of 1852, but not attended by injury to the works. The freshets thus far mentioned were not accompanied by ice, or they might have proved still more destructive. In January, 1865, an ice-freshet, which at the same time tore out two dams on the Youghiogheny, made great havoc at dam No. 4; in 1867 there was a rise which carried out the heaviest ice of twenty years and did much harm to dams Nos. 2 and 6 and to the locks at Nos. 4 and 5; and in 1868 similar damage was caused at dam No. 2.

As described in the history already quoted from, written in 1873, the six dams met successively in ascending from Pittsburgh had for their respective heights 8, 8, 8, 10, 13½, and 14 feet. The heights are stated now to remain substantially the same, though they have been slightly increased on the lower river.

Drainage areas of the Monongahela river and principal tributaries.

Stream and locality.	Drainage area.	Stream and locality.	Drainage area.
	Sq. miles.		*Sq. miles.*
Castleman's river (tributary of Youghiogheny river)	481	Tygart's Valley river at Beverly	215
Youghiogheny river above Castleman's river	446	Tygart's Valley river at Philippi	835
Youghiogheny river below Castleman's river	927	Tygart's Valley river at Grafton (below Fork creek)	1,276
Youghiogheny river at Falls City (above Beaver creek)	1,071	Tygart's Valley river at Valley Falls	1,320
Youghiogheny river at Connellsville	1,334	Tygart's Valley river at mouth	1,367
Youghiogheny river at mouth	1,766	Monongahela river below junction of West fork and Tygart's Valley river.	2,355
West fork of Monongahela river at Weston	147	Monongahela river at Fairmount (above Buffalo creek)	2,367
West fork of Monongahela river at Milford	410	Monongahela river at Morgantown (below Decker's creek)	2,737
West fork of Monongahela river at Clarksburg (below Elk creek)	602	Monongahela river above Cheat river	2,805
West fork of Monongahela river at mouth (junction with Tygart's Valley river).	988	Monongahela river below Cheat river	4,364
Cheat river at Saint George	952	Monongahela river above Youghiogheny river	5,655
Cheat river at Rowlesburg (below Salt Lick creek)	1,096	Monongahela river below Youghiogheny river	7,421
Cheat river at mouth	1,559	Monongahela river at mouth	7,625

THE YOUGHIOGHENY RIVER.

As regards extent of drainage basin, this stream ranks first among the tributaries of the Monongahela, commanding, as it does, the flowage from between 1,700 and 1,800 square miles of territory. Its source is about 30 miles south of the Pennsylvania line, and close upon the boundary between the extreme western portion of Maryland and the adjoining county of Preston, West Virginia. The North branch of the Potomac rises but a few miles to the southward, on the opposite slope of Great Savage mountain. For 35 miles, by direct line, the course

a *History of The Monongahela Navigation Company*, by an original stockholder, 1873.

b "It required more stone (14,297 cubic yards) and timber to repair the great breach of May, 1868, in dam No. 2, than were used in its original construction, by reason of the washing out of the bed of the river, which is generally an incompact conglomerate of sand and rounded gravel. The breach of 1843 required to fill it, in the language of Mr. Lothrop, the engineer, 'an immense mass of timber and stone that no power can remove'. And generally, if not uniformly, such repairs have never had to be repeated."

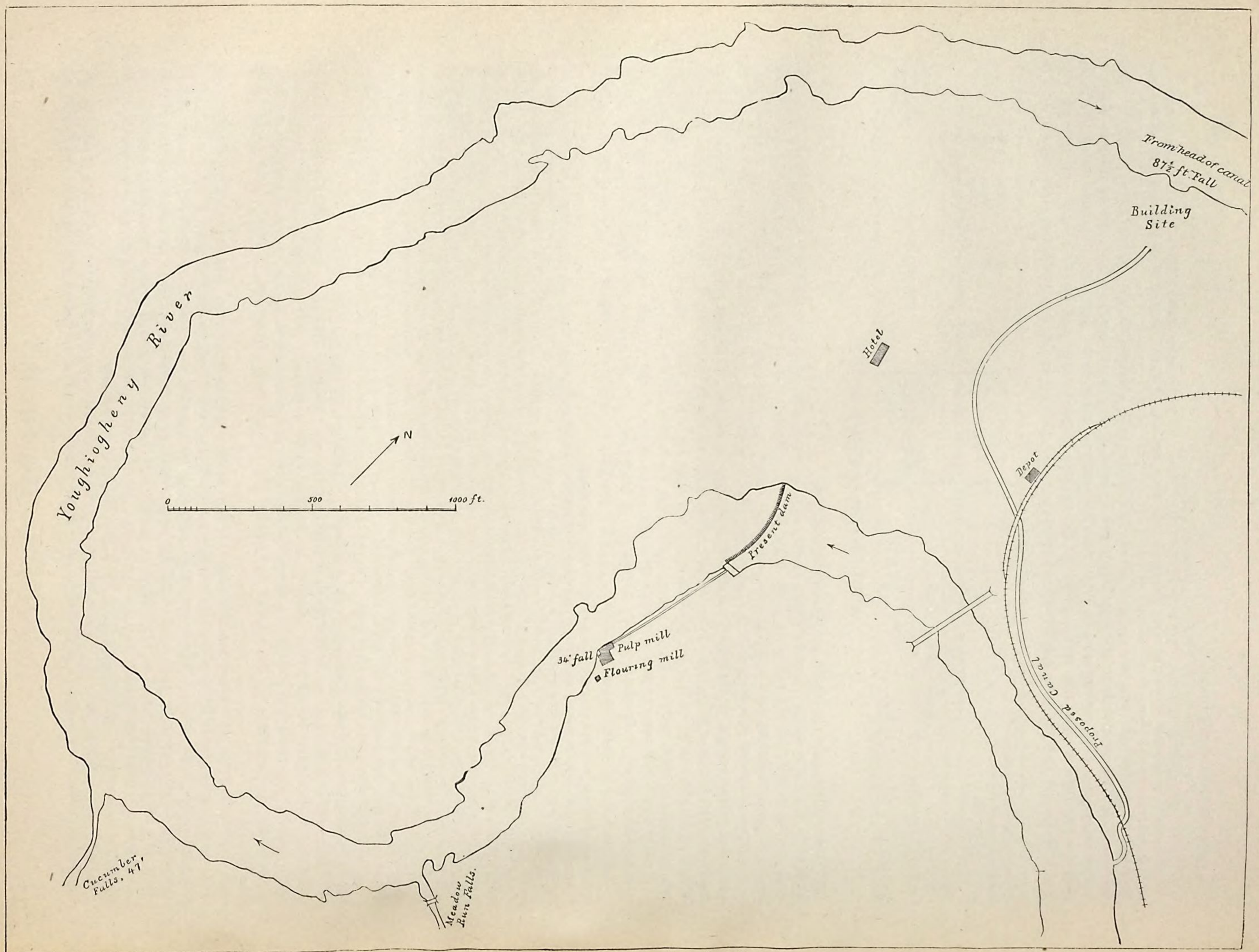
of the stream is almost due north, following the valley between Negro mountain on the east and the Briery mountains on the west. Six or 8 miles north of the Pennsylvania boundary the direction of flow changes to the northwest, carrying the river successively across Laurel hill and Laurel ridge, and on to its junction with the Monongahela, which is effected at McKeesport, some 15 miles above Pittsburgh. Measured by general course, the Youghiogheny has a length of about 85 miles. Much of the upper basin presents a very rugged surface and is well wooded. There is some rafting on the stream, but it is small in amount. Violent freshets occur, often aggravated by heavy runs of ice. At Connellsville it was stated that the common thickness of the ice, as it breaks up there at the close of winter, is about 12 inches; and that it seems to go out before the snow has melted very much in the mountains, not infrequently during a rather low stage of river, followed soon after by a rise from the mountains. In the middle of December, 1882, the river having fallen considerably within a few days, it was noticed by the author that in a narrow portion of the course a few miles below Connellsville ice was heaped up 5 or 6 feet high on either side near and upon the banks, and it was apparent that during the heavier breakings up at the end of the season the stream must often be an exceedingly difficult one to control. The principal freshet, with reference to the volume of water, is usually in June, and is caused by heavy rains; there is also a considerable rise in September. At such times much floating drift is brought down the stream. About the time when slack-water navigation was created on the Monongahela it was also extended up the Youghiogheny, by means of two dams and locks, as far as West Newton, 18 miles from the mouth, and much assistance was expected to the traffic on the main river. The expectation was not realized, however. The dams lasted but fourteen years, with long intervals of uselessness for want of repairs, and a great ice-flood in January, 1865, put an end to them. The charter of the company owning them is said to have since become extinct. It is stated that at present there is navigation for craft of 7 feet draught 4 miles above the mouth, and, except in extreme low water, 3 miles farther for those of not over 3 feet draught. Coal, coke, and other freight are brought by rail, and reshipped by water at the highest navigable point.

McKeesport, at the mouth of the river, is an important place of 8,000 inhabitants. Thence to Connellsville, about 40 miles, the Youghiogheny lies in a very narrow valley, shut in by high wooded hills. At times these rise abruptly from the water, and the railroad cuts reveal rocky strata; again they are less steep, and also leave a narrow strip of fertile land along the stream, cultivated for corn or other grain. The valley is in general too contracted to admit of extensive settlements. West Newton appears to be the principal place before reaching Connellsville, and has a population of 1,500; aside from this there are only small clusters of houses and the straggling, wretched-appearing quarters of the mining classes. The great industries of this valley are coal-mining and the burning of coke. Along the lower river the harder variety of bituminous coal is obtained, but in the vicinity of Connellsville a softer kind is mined and burned, or roasted, into coke, which is shipped away and extensively used in blast-furnaces. Long lines of the coke-ovens are to be seen near the river, while others stretch off among the hills, along short spur-lines of railroad. The Baltimore and Ohio railroad follows closely up the right or east bank, and in the winter of 1882–'83 a new line was being constructed on the opposite bank, designed, as it was said, to penetrate the coke region, and having for a northern connection the Pittsburgh and Lake Erie railroad. The only dam which was observed on this part of the river was at Port Royal, about half way between McKeesport and Connellsville; it was a low affair, with apparently but 1 or 2 feet of fall, and at one end was a distillery, where a small power might have been used. The width of the stream is quite irregular. Ripples appear now and then, where the depth is shallow and the current swift, and within a few miles of Connellsville there are one or two gravel shoals on which there is a moderate descent, but no rapids of any especial importance are encountered.

Estimate of power at Connellsville.

Stage of river.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		Effective horse-power (rated) of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.					
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	1 *foot fall.*	5 *feet fall.*	
Low water, dry year	10	12	9	8	39	1,334	120	13.6	70	50–100
Low water, average year							180	20.4	100	
Available 10 months, average year							300	34.1	170	

Connellsville is a borough of 3,600 inhabitants and is attractively located upon the river's bank. The hills which inclose the valley here recede from the stream, but at a distance they are to be seen rising, one ridge after another, high and thickly covered with timber. The river is at this point 250 or 300 feet wide, and is utilized to a small extent for power. A low wing-dam of logs and stone, with a facing of planks on the inshore side, extends some distance up stream parallel to the left bank and then out into the river. It is estimated to have cost at least $8,000, and diverts sufficient water so that, with the head of 5 feet gained by the fall in the river, power is furnished for operating steadily a small 2-run flouring-mill, the only interruption being an occasional stoppage of a day or two from high water. Ice causes more or less injury to the dam every year, and an average of perhaps $200 has to be spent in repairs. Opposite the head of the wing-dam a projecting point of land turns a portion of the flow of the



THE YOUGHIOGHENY RIVER AT OHIO PILE FALLS.

river to the right bank, where it is employed by a small flouring-mill and a planing-mill, but it is insufficient for their needs in low stages of water. Quite a heavy draught is said to be made upon the low-water volume of the stream, at a point a mile or so above, by a pump for supplying coke-ovens.

Ascending from Connellsville, the Youghiogheny soon assumes, and maintains to Falls City at least, 16 miles above, the characteristic features of a mountain stream. It is narrow and swift, almost a constant succession of ripples and rapids, many of them with heavy fall, and smooth water is exceptional.(*a*) Immense bowlders appear here and there in the stream and on the banks, and solid rock ledges are exposed at many points in the latter. High wooded hills rise on either hand, frequently with great abruptness from the water's edge, and never leaving a strip of meadow more than 100 or 200 feet wide. Indian creek enters from the east, and is the largest tributary in this section.

At Falls City, 56 miles by river above the mouth, occur the famous "Ohio Pile"(*b*) falls, where, by its rapid descent around a remarkable bend, the Youghiogheny offers a fine water-power, which is already partially utilized. In 1825 a commission, consisting of Colonel W. McKee, Colonel Roswell Lee, and Major George Talcott, was appointed by the United States government to select "a site for a national armory on the western waters", and it may be interesting to quote a portion of their report bearing upon the site at these falls:(*c*)

> The Youghiogheny river at this place makes a circuit of nearly 2 miles around a neck or tongue of land, about three-quarters of a mile in length, that projects from the foot of a mountain in its rear. At the upper side of this tongue, and near the extreme point of the mountain, is the commencement of the Ohio Pile rapids and falls, which terminate at the lower side opposite the point at which they begin, and 600 yards distant from it in a straight line. The whole descent is 87½ feet. The ground on the lower side, next the foot of the rapids, is advantageously disposed in steps or benches of sufficient width and at convenient distances below each other for the erection of buildings, and the successive application of the water to machinery in any manner that may be desired. Forty feet of the whole fall may thus be employed at a trifling expense. The bank then becomes steep and perpendicular, and the remaining part of the fall could not be conveniently used without extensive rock excavation. To convey the water to this site from above the falls will require a canal of 700 feet in length. The first 400 feet will pass through a strip of river bottom. The deepest cutting along the whole route is 30 feet, and occurs in passing a narrow ridge near the middle of the neck, consisting principally, as is supposed, of rock. A dam 4 feet high across the river will be necessary to procure a depth of water at the head of the canal sufficient to prevent it from being choked with ice, or obstructed by drift of any kind. The quantity of water which the river furnished at this place during an extremely dry season perhaps exceeded 100 cubic feet per second during the uncommon drought of 1823. If we regard the site of these falls, in reference to the security of the works that must be erected upon it from freshets, the perfect command of its water-power, and the cheapness with which it may be employed, it surpasses any that has ever come under our observation.

The river is here 150 or 200 feet wide. Within a few hundred feet it accomplishes a descent stated as 34 feet, and mainly included in abrupt pitches over masses of solid rock. In the banks are outcropping ledges of hard sandstone and conglomerate, and at points were noticed layers of sandstone inclined at a considerable angle and covered by horizontal strata. At the head of the falls a low dam crosses the river in a somewhat irregular line, arching well up stream; it is a log structure covered with planking, and is 400 feet in length, with the natural abutment afforded by a high rocky bank on the right, while at the opposite end is a timber and stone crib-work. From the latter point a flume conveys water perhaps 350 or 400 feet down the bank to W. W. Hartzell's wood-pulp mill, where a fall of something over 30 feet and 350 horse-power of wheels are in use; immediately adjoining, power is also employed in a 3-run flouring-mill with about the same fall. In some years there is throughout sufficient water for the full supply of these mills, and Mr. Hartzell was of opinion that if the whole flow of the river were utilized it would prove adequate in all ordinary years, but the dam is not tight and allows considerable waste, so that at times the power at the mills is curtailed.

Estimate of power at the Ohio Pile falls.

Stage of river.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.				Effective horse-power of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.							
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	*1 foot fall.*	*34 feet fall.*	*40 feet fall.*	*87½ feet fall.*	
Low water, dry year	10	12	9	8	39	1,071	100	11.4	390	460	1,000	380+
Low water, average year							150	17.0	580	680	1,490	
Available 10 months, average year							250	28.4	970	1,140	2,490	

Falls City is 74 miles from Pittsburgh, on the Pittsburgh division of the Baltimore and Ohio railroad, and is only a small village. The prevailing timber in the vicinity is hard wood, but spruce, poplar, and linn, all soft woods and suited to the manufacture of pulp, are also found in abundance. The water-privilege which has been described, together with a large tract of land in the vicinity, is said to be owned by the heirs of the late Andrew Stewart, of Washington, and to be under the control of Mr. D. S. Stewart, of that city, acting as attorney. The

a Between the crossing by the Baltimore and Ohio railroad near Oakland, Maryland, and that by its Fayette County branch near Connellsville, Pennsylvania, this stream has a fall of 1,458 feet, or an average for the whole distance of not far from 27 feet per mile.

b Supposed to be an Indian name signifying "beautiful falls".

c From *History of Fayette County*.

site is close by the railroad, and the full development of the fall would evidently furnish an important power. Mr. Hartzell holds part of the privilege, however, under lease, for the benefit of his pulp-works, and if water were diverted from above his dam across the neck of land in order to improve the entire fall, his rights would require to be purchased.

Above Falls City, up to Confluence, 8 or 10 miles beyond, the Youghiogheny appears rather less rough than below. There are still numerous rapids, but the fall is on the whole not so great, and there are some long stretches of comparatively smooth water. The valley, also, though very narrow in places, is yet generally more open than below Falls City. At Confluence the railroad branches off and follows up Castleman's river, which in point of drainage area is larger than the main stream above their junction. In general features the two streams are similar. The surrounding country, the flowage from which they receive, is very mountainous, with steep timbered slopes. No improvement of the main stream for power above the Ohio Pile falls was observed, and but one dam on Castleman's river, a few miles from the mouth.

THE CHEAT RIVER.

Across the eastern part of Randolph county, West Virginia, four forks, known respectively as the Shaver's or Main fork, Glade, Laurel, and Dry forks, flow in a northerly direction, and, successively combining in the southern part of Tucker county, form the main Cheat river. This then follows a somewhat irregular course to the north, and then northwest, passing from Tucker county through Preston and a corner of Monongalia, after which it crosses the state boundary into Pennsylvania, and running about 4 miles farther joins the Monongahela river. In extent of drainage basin it ranks second among the tributaries of that river, its basin including 1,559 square miles. From the head of the Main fork, the extreme source of which is in Pocahontas county, the distance by general course to the Monongahela is 100 miles. The head forks run in narrow valleys between parallel ranges of mountains, and are only 2 or 3 miles distant from one another, while the main river, like the Youghiogheny, cuts in turn across the Briery and Laurel Hill ranges.

The section of country drained by the Cheat river is in general rough and mountainous, especially wild toward the upper waters, sparsely settled, and but little cultivated. At Rowlesburg, a village of 400 inhabitants, the main line of the Baltimore and Ohio railroad crosses the river, but at no other point is it accessible by railroad. The upper basin is heavily timbered with spruce and hemlock, but the only cutting is of poplar, which is obtained principally in Randolph county, driven or rafted down to Rowlesburg, there sawed by steam-power and shipped by rail to eastern markets. About 4,000,000 feet of lumber is estimated to be sawed yearly, the work being carried on by three concerns, of which the largest is the firm of Eberly, Hinkle, & Co. There is said to be no sawing at any other points on the river. On the upper forks there are a few small flouring- and grist-mills that do all the grinding for which there is any demand, and a mile or two below Saint George there is reported to be a small mill on the main stream, but no power is utilized anywhere below. Nevertheless, the river is described as well suited to use for water-power if there were demand for such improvement. The descent is rapid throughout, and especially in the "narrows", in which it cuts through the mountains below Rowlesburg, which is regarded as the most rapid portion of its course. From Rowlesburg to the mouth the total fall is about 546 feet, averaging about 14 feet to the mile. The fall is usually in rapids and ripples joining long eddies or pools. The current is very swift, so much so that it is difficult to hold logs in booms, and this has been the chief obstacle in the way of more extensive lumbering operations on the river. It is considered a fine stream for log-driving and rafting, except in one feature, and that is its obstruction by many large bowlders.

The valley is, in general, narrow and deep, hemmed in by high mountains with steep rugged slopes. Here and there, however, these open out and inclose a fertile intervale of farming land. Such an intervale may be seen just below Rowlesburg from the Baltimore and Ohio railroad opposite, and there is said to be another large opening, a couple of miles more or less in extent, near Saint George. As a rule, the river-bed is composed of ledge rock, probably sandstone, a variety of which, known as "Cheat River bluestone",(*a*) has been extensively quarried at Rowlesburg, shipped to Baltimore, and used in several prominent buildings. At the locality mentioned the Cheat averages about 250 feet in width. It rises rapidly, but not very high, and hardly reaches its height before it begins to recede as quickly as it rose. Mr. Eberly, of the firm of Eberly, Hinkle, & Co., gave the ordinary rise at Rowlesburg as only about 5 feet above extreme low water, and stated that he had never known a freshet there of more than 7 feet, except in one instance, when a height of 10 feet was reached. The stream is sometimes visited by sudden and extraordinarily rapid fluctuations, and is also very deceptive, in accordance with its name of "Cheat". There may be a heavy rain in the country about Rowlesburg without the river's being apparently at all affected; while, again, with the weather fine there, a local storm at some point above will produce a quick and important rise. This action may doubtless be explained by the steep mountainous slopes at the head-waters rapidly shedding the rains of heavy showers into the water-courses, and by the fact that the drainage basin is also rather more expanded there than below. The river runs very low in the dry season, and sometimes continues so for a couple of months.

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a In the vicinity of Rowlesburg the prevailing rock is described as being sandstone, mostly red and gray in color. The bluestone is a compact blue sandstone, easily worked and taking a fine finish. It has been used at Baltimore in the office buildings of the Baltimore and Ohio railroad, in the Johns Hopkins hospital, and for other structures.

Estimate of power at Rowlesburg.

Stage of river.	RAINFALL ON BASIN.(a)					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power per foot fall.
	Spring.	Summer.	Autumn.	Winter.	Year.			
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	
Low water, dry year	10	12	9	9	40	b 1,096	90	10.2
Low water, average year							130	14.8
Available 10 months, average year							250	28.4

a The rainfall records for the Monongahela basin are very few in number, and the figures here assumed are to be regarded as only roughly approximate.
b Below Salt Lick creek.

THE TYGART'S VALLEY RIVER.

This stream takes its rise a few miles northwesterly from the head of the main fork of the Cheat river, near the extreme southern boundary of Randolph county. It flows northerly through the county, skirting the eastern slope of Rich mountain, then cuts across the ridge, and traverses in succession the counties of Barbour, Taylor, and a portion of Marion, uniting in the latter with the West fork of the Monongahela. Neglecting the minor bends, the Tygart's Valley river has a length of 75 miles. Its drainage basin contains 1,367 square miles, and varies in general in width between 18 and 30 miles. From Grafton to the mouth, a distance which by map measurement appears to be about 18 miles, the right bank of the stream is closely followed by the Baltimore and Ohio railroad, which crosses at the mouth, and at Fairmount, a little beyond, turns abruptly to the west on its way to Wheeling. In the winter of 1882–'83 a narrow-gauge railroad was also being constructed from Grafton up the river toward Philippi, which lies about 15 miles due south; but above the latter point the valley is not accessible by railroad. The town of Grafton has a population of 3,000, and is the only place of much importance on the stream. A few miles above that locality heavy rapids are said to begin, the course lying for a number of miles in a narrow valley, and the river very rough all the way. At Grafton there is a smooth, strong current, the width between banks being 275 or 300 feet. Thence to the mouth the stream lies between high hills which are partially wooded. At times their outlines are well rounded, but again they rise precipitously with rocky sides. Where the hill-slopes are gentle there is some cultivation, but there is scarcely any bottom-land. A mile or two below Grafton there is a considerable shoal, though short. The flow then continues smooth but strong for perhaps half a dozen miles, to Valley Falls, when the character of the stream suddenly changes. It narrows down, and descends rapidly over a rocky bed in successive short pitches occurring at intervals of a few hundred feet through a total distance of between 1 and 2 miles. Thence to the mouth the fall is less rapid, but there are frequent ripples and shoals. The water of the stream is of a decidedly greenish color, in marked contrast to that of the West fork, which was observed to be of a reddish muddy appearance, the line being sharply drawn between the waters of the two for some distance below their junction.

Between Grafton and the mouth of the river there are four dams—one at Valley Falls, and the other three at points below; these latter are low affairs, in one case a mere wing running out to an island, and the use of power, by small grist-mills, is insignificant. The privilege at Valley Falls, some 7 or 8 miles below Grafton, is a fine one, not only from the amount of available fall, but also because of the security and convenience of the site for building. Two abrupt pitches over ledges of sandstone rock occur here in a distance of 200 feet, with a third, less sudden, a little way below. A hill rises steeply on the left, while the opposite bank presents an open space, with a gentle ascent toward the railroad, which is close at hand. At the head of the falls a low framed dam extends across in an irregular line, and a wing running parallel to the right bank diverts water to a saw-mill 300 or 400 feet below. This mill is owned by Theodore Bush & Co., and contains a 62-inch circular saw, and stave machinery; a little power is also employed for a 2-run grist-mill. From the water-surface above the dam to the pool opposite the tail-race the fall is about 26 feet. An additional fall of 15 feet could be gained by extending the head-race 500 feet farther, but the extension would have to be carried through a rocky bank. The available power of the privilege may be estimated as below:

Estimate of power at Valley Falls.

Stage of river.	RAINFALL ON BASIN.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.			Effective horse-power of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.			1 *foot fall.*	26 *feet fall.*	40 *feet fall.*	
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*				
Low water, dry year	10½	12	8½	10	41	1,320	100	11.4	300	460	50
Low water, average year							170	19.3	500	770	
Available 10 months, average year							280	31.8	830	1,270	

In years past there has been much rafting of hewn timber on this river, but the amount is said to be falling off. Poplar and oak are the principal varieties of trees now cut, the logs being driven down from the upper waters and sawed at various points along the course, usually by steam-power. There is a large amount of sawing done at Grafton and vicinity; and at Bush & Co.'s mill at Valley Falls about 3,000 logs were cut during 1882, furnishing an average of 300 or 400 feet of lumber each.

THE WEST FORK OF THE MONONGAHELA RIVER.

Rising in the western part of Upshur county, the West fork, the only remaining important tributary of the Monongahela to be described, passes westerly into Lewis county, and then by a general northerly course through Harrison county and into Marion, where it joins the Tygart's Valley river. Its length is about 60 miles, measured along the general direction of flow, and the drainage area is 988 square miles, the stream ranking in extent of basin fourth among the tributaries of the Monongahela. The Baltimore and Ohio railroad crosses at Clarksburg, and a short narrow-gauge line runs from that point up the valley to Weston, about 20 miles distant. Other portions of the valley are without direct railroad communication. The places above mentioned are the principal ones on the stream, the town of Clarksburg having in 1880 a population of 2,300, and that of Weston 1,500. The former is a scatteringly-built town, with little manufacturing and apparently little wealth. The country drained by the West fork is mainly an agricultural section, with wheat and corn for its chief productions. The soil, in Harrison county at least, is largely clay and lime, the hills and bottoms both productive, the former especially adapted to the raising of wheat. The timber has been generally cleared away, except about the head-waters of the river, where important amounts of oak and poplar remain; poplar is the only kind of timber, however, of which very much is cut at present, the logs being driven down stream, sawed, and the lumber shipped by rail to be employed in the manufacture of furniture, sashes, doors, blinds, and other articles. No iron worth mentioning is found; but the hills and mountains abound in coal, which is mined to a considerable extent. There is but a moderate amount of coke-burning, and Harrison county is said to contain not more than 50 or 60 ovens.

At Clarksburg the river is 175 feet wide. It is described as having generally in that portion of its course a bed of solid ledge rock, mostly a hard blue sandstone. The banks are usually of good height, composed of clay and loam, with sometimes a little gravel, and are but little overflowed during freshets. There is a good current, with frequent rapids, but there are no abrupt natural falls. Within a short distance from the mouth there is said to be a saw-mill, and at intervals above power is also utilized by small flouring-mills, having in most cases about two runs of stones and employing low falls of from 3 or 4 up to 7 feet. There are eight or ten powers in use, altogether, below Weston, or in say 35 or 40 miles of general course from the mouth. At Clarksburg a fall of 7 feet is used by John R. Steel for a flouring- and saw-mill, the former containing three pairs of buhr-stones, and the latter a 60-inch circular saw. Power is taken from two water-wheels estimated to furnish together 60 horse-power or more. About 2,500 logs were sawed at this mill in 1882, averaging 300 or 400 feet per log. The dam is a framed structure, 12 feet wide at the base, from 7 to 9 feet high, and with 244 feet length of overflow. It was built part in 1867 and part in 1871. The face is carried up vertically and made close with timbers, the interior of the whole structure being compactly filled with rock. A sheeting of oak planks, from 1½ to 2½ inches thick, covers the dam, which rests upon and is bolted to a bed of solid rock. A chute 45 feet wide and 60 feet long permits the passage of logs down stream. At one end of the dam is the mill, while the opposite end is protected by a crib-work abutment 18 by 30 feet in plan. At other points on the river the dams are said to be built variously of stone, hewn timber, and logs, and to stand well.

Estimate of power at Clarksburg.

Stage of river.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		Effective horse-power of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.					
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches*	*Sq. miles.*	*Cubic feet.*	*1 foot fall.*	*7 feet fall.*	
Low water, dry year	10½	12	8½	10	41	602	30	3.4	24	60
Low water, average year							50	5.7	40	
Available 10 months, average year							90	10.2	70	

For Steel's mill the supply of water is commonly sufficient nine months in the year for running at full capacity, but during the rest of the time steam has to be relied upon. The stream does not often get very low before June, and in some years no shortage occurs at all, while in others it exists for as long a time as four or even six months, covering most of the period between April and November. The country drained is subject to heavy droughts, which appear to have been aggravated by the general clearing away of timber from the surface, and is not supplied with good springs. During times of unusual scarcity the stream can even be crossed dry-shod at Clarksburg, and the use of water-power has to be entirely abandoned. Not much snow falls in this section, and a depth of 8 or 10 inches is seldom exceeded, even in very rare instances. Ice has been known to form 18 inches thick at Clarksburg,

but commonly it does not reach a greater thickness than 6 or 8 inches, and in some winters there is scarcely any. The West fork is visited by a freshet in April, sometimes by one in June, and important rises are liable to come, now and then, in almost any of the other months of the year; in fact, the phenomena of snow, ice, and rain are all very irregular in their appearance and extent.

Table of utilized power on the Monongahela river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Monongahela river	Ohio river	Pennsylvania	Allegheny	Saw	1	8	70	.....	Port Perry.
Do	do	West Virginia	Monongalia	Flouring and grist	2	9	58	.....	
Do	do	do	Marion	do	1	5	16	.....	
Do	do	do	do	do	2	4½	45	.....	
Sundry small streams.	Monongahela river	Pennsylvania	Westmoreland	do	1	10	20	25	
Do	do	do	Washington	do	6	95	135	148	
Do	do	do	do	Saw	1	10	16	.....	
Do	do	do	Greene	do	1	8	30	.....	
Do	do	do	do	Woolen	2	26	22	20	
Do	do	do	do	Flouring and grist	6	87	116	16	
Do	do	do	Fayette	do	19	244+	328	201	
Do	do	do	do	Woolen	2	32	30	30	
Do	do	do	do	Saw	6	69+	81	.....	
Do	do	West Virginia	Monongalia	do	3	29	67	.....	
Do	do	do	do	Flouring and grist	10	113	218	98	
Do	do	do	Marion	do	10	75	174	125	
Do	do	do	do	Saw	4	30	54	.....	
Do	do	do	Preston	Flouring and grist	3	26½	48	25	
Ten-Mile creek and tributaries.	do	Pennsylvania	Greene	do	8	57+	227	130	
Do	do	do	do	Saw	1	8	25	.....	
Do	do	do	Washington	Flouring and grist	6	73½	192	.....	
Youghiogheny river	do	do	Fayette	do	2	6	25+	.....	Connellsville.
Do	do	do	do	Planing	1		30	.....	
Do	do	do	do	Flouring and grist	1	30–34	30±	.....	Falls City.
Do	do	do	do	Wood-pulp	1		350	.....	
Castleman's river and tributaries.	Youghiogheny river	do	Somerset	Flouring and grist	14	268	306	81	One mill returned for main river.
Do	do	do	do	Saw	18	240+	248	.....	
Do	do	do	do	Tannery	1	13	12	.....	
Do	do	do	do	Woolen	6	65	78	32	
Other tributaries	do	do	do	do	2	11	11	.....	
Do	do	do	do	Tannery	1	16	15	.....	
Do	do	do	do	Saw	1	20	16	.....	
Do	do	do	do	Flouring and grist	4	62	70	30	
Do	do	do	Fayette	do	16	233	334	86	
Do	do	do	do	Saw	2	28	7	.....	
Do	do	do	do	Tanneries	2	30	43	.....	
Do	do	do	do	Chair shops	2	15	4	.....	
Do	do	do	Westmoreland	Flouring and grist	4	68	100	55	
Do	do	do	do	Paper	1	26	100	150	
Do	do	do	do	Saw	2	34	45	.....	
Do	do	do	do	Tannery	1	18	8	.....	
Do	do	West Virginia	Preston	Flouring and grist	1	14	10	.....	
Cheat river and tributaries.	Monongahela river	do	do	do	19	289+	335	57	
Do	do	do	do	Saw	8	100	109	.....	
Do	do	do	Tucker	do	2	17	14	.....	
Do	do	do	do	Flouring and grist	1	9	12	.....	
Do	do	do	Monongalia	do	2	12	35	.....	
Do	do	Pennsylvania	Fayette	do	1	10	8	.....	
Tygart's Valley river	do	West Virginia	Marion	Saw	1	26	50±	.....	Valley Falls.
Do	do	do	do	Flouring and grist	1				
Do	do	do	do	do	3	17	32	.....	
Do	do	do	Barbour	do	4	16	54	.....	
Do	do	do	Randolph	do	2	35	20	.....	
Tributaries	Tygart's Valley river	do	do	do	4	48	79	.....	
Do	do	do	do	Saw	3	30	44	.....	
Do	do	do	Upshur	do	2	14	28	.....	
Do	do	do	do	Flouring and grist	5	42½	124	.....	
Do	do	do	Barbour	do	7	92	127	35	

Table of utilized power on the Monongahela river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Tributaries	Tygart's Valley river	West Virginia	Preston	Flouring and grist	2	34	40	40	
Do	do	do	do	Saw	1	20	20		
Do	do	do	Taylor	do	2	17	54		
Do	do	do	do	Flouring and grist	5	55½	120	25	
West fork of Monongahela river.	Monongahela river	do	Marion	do	2	8½	29		
Do	do	do	do	Saw	1	4	10		
Do	do	do	Harrison	do	1	7	60		Clarksburg.
Do	do	do	do	Flouring and grist	1				
Do	do	do	do	do	1	6	20		
Do	do	do	do	Saw	1		8		
Do	do	do	do	Flouring and grist	1	6	30	36	
Do	do	do	Lewis	do	2	6+	40	64	
Tributaries	West fork of Monongahela river.	do	do	do	3	17	60	36	
Do	do	do	Harrison	do	12	116	330	225	
Do	do	do	do	Saw	2	16	56	18	
Do	do	do	Barbour	do	2	48	30		
Do	do	do	Taylor	Carpentering	1		2		
Do	do	do	do	Furniture	1		2		
Do	do	do	do	Flouring and grist	2	16	33		
Do	do	do	Marion	do	1	7	16		

THE BEAVER RIVER.

This stream may be regarded as formed at the city of New Castle, in Lawrence county, western Pennsylvania, by the union of two tributaries, the Shenango and Neshannock rivers. This junction is about 40 miles northwesterly from Pittsburgh and within 8 miles of the Ohio boundary. From New Castle the course of flow is southerly, passing over a distance probably amounting, if the bends be closely followed, to about 30 miles, and joining the Ohio river at Beaver. Besides the tributaries already mentioned, which come from the northward through Mercer and Crawford counties, the main stream receives from the west, within a short distance below New Castle, the Mahoning river, which drains portions of several of the northeastern counties of Ohio. About midway between the mouth of the Mahoning and the Ohio river Conoquenessing creek enters from the east, and is the last important affluent.

Drainage areas.

	Square miles.
Shenango river at New Castle	765
Neshannock river at New Castle	235
Mahoning river at mouth	1,072
Conoquenessing creek at mouth	810
Beaver river at New Castle, below junction of Shenango and Neshannock rivers	1,000
Beaver river below Mahoning river	2,095
Beaver river below Conoquenessing creek	2,964
Beaver river at mouth	3,030

The territory embraced within the water-shed lines of the Beaver river, amounting, as shown in the preceding statement, to 3,030 square miles, has valuable deposits of coal and iron, is but moderately timbered, and possesses in general a flat or gently-rolling surface. The city of New Castle, at the head of the main river, is an important place, with a population in 1880 of 8,400, and has large iron furnaces. For a mile or two below, the valley appears to range between a quarter and a half mile in width, the river-banks being low and succeeded by wide cultivated flats. The valley then contracts and continues narrow down to Beaver Falls, with high hills rising abruptly from the stream. Through this section the space is too narrow for the convenient location of villages even, and none of importance are encountered; but within 4 miles of the mouth the banks become quite thickly settled, and we find successively the boroughs of Beaver Falls, with 5,100 inhabitants; New Brighton, 3,700; and, at the junction with the Ohio, Rochester on the east and Beaver on the west bank, having populations, respectively, of 2,600 and 1,200.

The Pittsburgh, Fort Wayne, and Chicago, and the Erie and Pittsburgh railroads follow the main river closely, the former ascending for about 9 miles from the mouth, while the latter continues to New Castle and thence up the Shenango river. The Neshannock and Mahoning branches are also closely skirted by railway lines, giving easy

communication in nearly all directions. Years ago the Beaver river possessed a system of slack-water navigation extending from the Ohio river up to New Castle, and from that point connection was had with lake Erie through the Erie canal of Pennsylvania, which followed up the valley of Shenango creek, crossed the water-shed, and descending the valley of Conneaut creek passed on northeasterly to the city of Erie. This navigation route no longer exists, however; the canal has been abandoned, and the only dam between New Castle and Beaver Falls is shortly below the former point.

According to a report made in December, 1867, by W. Milnor Roberts, the fall from the head of New Castle pool to low water in the Ohio river is 129 feet.(*a*) By the elevations obtained in connection with the second geological survey of the state the fall appears as 133 feet. But of this amount 52 feet, or about 40 per cent., occurs within the 4 miles from the crest of the Beaver Falls dam to the mouth of the river, leaving the balance of 80 feet, more or less, to be distributed over say 25 miles above, in which the average descent is therefore but little over 3 feet per mile. Substantially all of the 52 feet of fall mentioned is included within three privileges: that at Beaver Falls, covering 19 or 20 feet; a second, 1 or 2 miles below, supplying mills both on the New Brighton side and at Fallston, on the opposite bank, and embracing a fall of 16 or 18 feet; and a third at Bridgewater, near the mouth, with a fall of 12 feet. The latter privilege is not utilized for power, and the owners, Messrs. Minor & Co., and M. T. & S. Kennedy, of Fallston, would not willingly lose control, as they depend upon it for locking up rafts from the Ohio river to their mills. This lower portion of the Beaver river is under the influence of freshet backwater from the Ohio, which sometimes causes a rise of 25 or 30 feet below the New Brighton dam, submerges that structure under 10 or 15 feet of water, and at Fallston at least overflows the banks and enters the mills. Serious trouble from backwater lasts from two or three days to one or two weeks. Notwithstanding the quite expensive nature of the improvements at Beaver Falls and New Brighton, the danger and hinderance arising from floods, and the fact that coal can easily and cheaply be obtained, the manufacturers seem well satisfied with their hydraulic power, and consider it more economical for their purposes than steam.

Table of elevations on the Beaver river and its principal tributaries.(*a*)

Stream.	Locality.	Approximate distance from mouth.(*b*)	Altitude above ocean-level.	Remarks.
		Miles.	*Feet.*	
Neshannock river	Hope Mills	18.5	1,107	Elevation of rails at station by levels of Oil City and Chicago railroad.
Do	Neshannock Falls	9.0	992	Do.
Do	New Castle (mouth of river)	0.0	799	Water-surface in New Castle pool.
Shenango river	Jamestown	52.5	979	Elevation of rails of the Erie and Pittsburgh railroad at crossing of the Franklin division of the Lake Shore and Michigan Southern railroad.
Do	Shenango	45.0	941	Elevation of rails at station by levels of Erie and Pittsburgh railroad.
Do	Sharon	22.7	853	Do.
Do	New Castle (mouth of river)	0.0	799	Water-surface in New Castle pool.
Mahoning river	Warren, Ohio	35.0	875	Elevation of rails at station by levels of Ashtabula and Pittsburgh railroad.
Do	Mahonington	(*c*)	789	Do.
Beaver river	New Castle	30.0±	799	Water-surface in pool.
Do	Mouth	0.0	666	Low water in Ohio river. W. Milnor Roberts' report of 1870 gives the elevation as 671.57 feet.

a Elevations taken from report on *Levels above Tide, Second Geological Survey of Pennsylvania.*
b By map measurement.
c Close by mouth.

From New Castle down to Beaver Falls the river appears to average as much as 300 feet in width. The dam at the latter point is a fine structure of timber, running straight across the stream, with masonry abutments, vertical face, and no apron; it is about 15 feet high and probably 500 or 600 feet in length. The river-bed is rocky, and rapids extend below the dam. During the period when the Beaver was utilized for navigation, boats passed through a lock and canal at the east end of the dam, and water is still conveyed some distance down that bank to a flouring-mill; but with that exception the power of the privilege is owned and employed on the Beaver Falls or west bank. Water is admitted to a hydraulic race through a substantial timber bulkhead, in which there are five gate-openings, each 5½ feet wide. Each gate is hung by two chains passing over a wooden axle, which is turned by lever-bars and held in place by a ratchet. The fall of this privilege varies somewhat at the different mills, but, as nearly as could be ascertained, amounts to between 19 and 20 feet at the foot of the race. The manufacturing sustained is quite extensive, the largest concerns using power being the Pittsburgh Hinge Company, manufacturing mainly chain and wire, the Beaver Falls Steel Works, and the Beaver Falls Cutlery Company; power is also employed by three planing-mills, a flouring-mill, a pottery, and the borough water-works. The entire power on the race is nominally divided into 200 equal shares, and the oversight of repairs, adjustment of gauge-boards, and other similar duties are intrusted to a committee of the manufacturers. There is commonly a sufficient supply of

a Report to the President and Managers of the Erie Canal Company, of Pennsylvania.

water for all demands, even in a low summer stage, but in exceptionally dry years a shortage has been known to exist for three or four weeks. Ice gives no trouble here of consequence, but the stream is a wild one during freshets, and in an extreme case there has been a depth of 7 feet of water on the dam, the adjoining bank having been submerged at the time. In an ordinary rise, however, there is seldom more than 3 or 4 feet of water running over the dam.

Estimate of power at Beaver Falls.

Stage of river.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		Effective horse-power of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.					
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	1 *foot fall.*	19 *feet fall.*	
Low water, dry year	9½	11	10	8½	39	2,994	300	34.1	650	*a* 590+
Low water, average year							450	51.1	970	
Available 10 months, average year							700	79.5	1,510	

a Returns not complete.

The next dam is a mile or more below the one just described. At the road-bridge between the two the river has a width of about 450 feet. The bed continues rocky, but loses this character a little below the New Brighton dam, and is said to be then composed of gravel and bowlders to a great depth. In construction the dam at New Brighton is described as similar to that at Beaver Falls, it being a timber structure with a height of about 15 feet. There are really three dams in place, each having been built a little below and a little higher than the previous one; the present or main dam was built some ten years ago, and its cost, with abutments, is estimated to have been $20,000. There are rapids below the dam and a race follows down each bank, that on the east being in the borough of New Brighton. On the west side there is an abrupt rise away from the stream, and the race is continued for some distance, down to Fallston, before being drawn upon by mills. The fall in use is stated as 16 feet near the dam on the New Brighton side, but increases somewhat below, and at Fallston is 18 feet, which may be taken as the extreme amount. As at Beaver Falls, the entire power of the privilege is assumed at 200 shares, but here it is equally divided between the two sides of the stream. The New Brighton race is perhaps a quarter of a mile long. The largest establishment supplied from it is the flax-mill of Messrs. Bentley & Gerwig, manufacturers of hemp binding-cord and flax twines, and employing about 160 hands. The New Brighton water-works are operated by power from this race, and it is also drawn upon for running two flouring- and two planing-mills, scouring-works, and a machine-shop—all these of small or moderate size.

On the opposite side of the river the race is probably as much as half a mile long. There is little of interest at Fallston except the mills, which are scattered for a thousand feet along the lower part of the race, close to the river-bank, and not out of reach of high freshets. The principal works here are those of W. P. Townsend & Co., manufacturers of rivets, and M. T. & S. Kennedy, makers of lead-kegs; the Standard Horse Nail Company and the Keystone Portable Steam Driller Company also have works at this point, and power is further utilized by a saw- and planing-mill, a woolen-mill, a grist-mill, a machine-shop, and an establishment for making wooden handles; but these are all comparatively small.

Estimate of power at the New Brighton and Fallston privilege.

Stage of river.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		Effective horse-power of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.					
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	1 *foot fall.*	18 *feet fall.*	
Low water, dry year	9½	11	10	8½	39	2,995	300	34.1	610	*a* 682+
Low water, average year							450	51.1	920	
Available 10 months, average year							700	79.5	1,430	

a Returns not complete.

Both at New Brighton and at Fallston a share of water entitles the owner to draw through an opening of 7½ inches width over a gauge-board or weir. At Fallston, at least, the weirs are adjusted from the results of actual experiments, and are 10 inches lower at the foot of the race than where it is first drawn upon, 1,000 feet above. The power of the privilege is pretty thoroughly utilized in low stages of river. At New Brighton there is not in ordinary years any scarcity of water, and at Fallston the shortage ranges from nothing to a month in duration during different years. At this point there was, when it was visited, in December, 1882, opportunity for another manufacturing concern, for which 7 shares of water could be obtained, and on the New Brighton side it was stated that moderate powers could doubtless be secured. As has already been stated, there is heavy backwater here from the Ohio, but the hinderance does not last long.

Table of utilized power on the Beaver river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.
						Feet.	*H. P.*	*H. P.*
Beaver river (*a*)	Ohio river	Pennsylvania	Beaver	Blankets, etc	1	Total utilized fall, 37–38 feet.	14	
Do	do	do	do	Coffins, burial cases, and undertakers' goods.	1		90	
Do	do	do	do	Cooperage	1		76	50
Do	do	do	do	Cordage and twine	1		150	200
Do	do	do	do	Cutlery and edge-tools	2		155	120
Do	do	do	do	Flouring and grist	5		245	
Do	do	do	do	Hardware	1		90	
Do	do	do	do	Iron castings and finishings	1		7	
Do	do	do	do	Iron nails, spikes, etc	1		40	
Do	do	do	do	Lead-kegs	1			
Do	do	do	do	Lumber, planed	5		150+	
Do	do	do	do	Machinery	2		10+	15
Do	do	do	do	Pottery	1			
Do	do	do	do	Pumping-works, operated for water-supply.	2			
Do	do	do	do	Rivets	1			
Do	do	do	do	Saw	1		60	
Do	do	do	do	Scouring-works	1			
Do	do	do	do	Steam-drills	1			
Do	do	do	do	Steel-works	1			
Do	do	do	do	Wire	1		80	90
Do	do	do	do	Wooden handles	1		30	
Do	do	do	do	Woolen	1		25	
Conoquenessing creek and tributaries.	Beaver river	do	Butler	do	3	14½+	30	
Do	do	do	do	Saw	3	16 +	65	
Do	do	do	do	Flouring and grist	19	216	529	262
Do	do	do	Mercer	Iron castings	1	7	8	
Do	do	do	do	Flouring and grist	7	67	157	
Do	do	do	Lawrence	do	1	22	30	
Do	do	do	Venango	do	1	12	20	
Sundry small streams	do	do	Lawrence	do	1	28	80	85
Do	do	do	do	Woolen	3	33	29	
Mahoning river	do	Ohio	Mahoning	Saw	1	10½	15	
Do	do	do	do	Flouring and grist	1		40	
Do	do	do	do	do	3	29	140	100
Do	do	do	Trumbull	do	1	16	35	
Do	do	do	do	Woolen	1		16	
Do	do	do	do	Saw	1	6½	12	
Do	do	do	do	Flouring and grist	4	28	239	50
Do	do	do	Portage	Flax, dressed	1	5½	15	
Do	do	do	do	Flouring and grist	1	8	50	
Do	do	do	do	Saw	1		20	
Tributaries	Mahoning river	do	do	Cooperage	1	11	25	
Do	do	do	do	Flouring and grist	1	42	17	25
Do	do	do	do	Machinery	1	15	10	20
Do	do	do	do	Sashes, doors, and blinds	1	15	20	
Do	do	do	do	Saw	2	51	35	25
Do	do	do	do	Tannery	1	13	10	
Do	do	do	do	Wooden packing-boxes	1	17	20	25
Do	do	do	Trumbull	Tannery	1	22	10	
Do	do	do	do	Flouring and grist	6	93	165	110
Do	do	do	Columbiana	do	1	14	40	38
Do	do	do	Stark	do	3	35	76	93
Do	do	do	Mahoning	do	2	11	36	
Shenango river	Beaver river	Pennsylvania	Lawrence	do	2	8½	60	
Do	do	do	Mercer	do	1	7	24	
Do	do	do	do	Saw	1		8	
Do	do	do	do	Flouring and grist	8	46	257	
Do	do	do	Crawford	do	1	18	40	
Sundry small tributaries	Shenango river	do	do	do	2	30	65	20
Do	do	do	do	Saw	2	43	37	20
Do	do	do	Lawrence	Flouring and grist	1	18	35	
Do	do	do	Mercer	do	8	86½	269	15

a Power on Beaver river utilized at Beaver Falls, New Brighton, and Fallston.

Table of utilized power on the Beaver river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.
						Feet.	*H. P.*	*H. P.*
Sundry small tributaries	Shenango river	Pennsylvania	Mercer	Saw	1	7	30	.....
Do	do	Ohio	Trumbull	Flouring and grist	1	13	14	14
Do	do	do	Ashtabula	do	2	28	50	30
Neshannock river and tributaries	do	Pennsylvania	Lawrence	do	5	77	225	.....
Do	do	do	do	Paper	1	12	40	12
Do	do	do	do	Saw	2	22	44	.....
Do	do	do	do	Woolen	3	21+	36	20
Do	do	do	Mercer	do	1	12	10	.....
Do	do	do	do	Flouring and grist	8	127	172	85
Do	do	do	do	Saw	5	38+	54	.....

THE MUSKINGUM RIVER.

An area of 7,740 square miles, embracing the greater part of eastern Ohio, is tributary to the Muskingum river. Of the total amount, about 4,700 square miles contributes its drainage from above Coshocton, where the Tuscarawas and Walhonding unite to form the main river; one-half of the remainder is gained from Wills creek and the Licking river, and the balance from sundry small creeks. From Coshocton the river flows southerly and then southeasterly to the Ohio, which it joins at Marietta, having passed through a distance of about 110 miles and traversed in succession a portion of Coshocton county and the counties of Muskingum, Morgan, and Washington. The extreme sources of the Walhonding river are in the counties of Richland and Ashland, 35 or 40 miles southeasterly from Sandusky; those of the Tuscarawas are in Medina and Summit counties, 25 or 30 miles southerly from Cleveland. Where the Ohio canal crosses, in the vicinity of Akron, the summit between the adjoining portions of the Cuyahoga and Tuscarawas River basins, the elevation is only about 400 feet above low water in the Ohio at Marietta, and nearly the same above the surface of lake Erie. It is apparent, therefore, that the average descent of the country to the southward toward the Ohio is small, amounting to not much more than 3½ feet per mile if we reckon in a direct line from the summit-level of the canal to the mouth of the Muskingum. From low water at Dresden, 91 miles by river above Marietta, the fall to low water in the Ohio is only 130 feet, an average of about 1.4 foot per mile.

The drainage basin of the river we are considering is quite regular in shape, gradually expanding toward the upper waters, where a width of 90 miles in an east-and-west line is reached. It is rich agriculturally and contains valuable coal-fields. The western boundary of the Pittsburgh coal deposit crosses the Ohio river in the vicinity of Steubenville, and striking southwesterly so as to include a strip in Ohio ranging from 50 miles in width downward approaches the river again in Gallia county; the western limit of the Nelsonville coal deposit runs approximately parallel to the one just described, at a distance beyond varying from 20 to 40 miles. In the southern counties of the Muskingum basin the soil has resulted from the disintegration of the native rocks, and the country is poorly watered; its surface is extremely rough and irregular, cut in every direction by valleys, between which rise high hills. To the northward the surface becomes less broken, though still gently undulating; the soil has been derived from drift materials, is sandy or gravelly in nature, but very fertile, and is variously underlaid by sandstone, shale, coal, and limestone. The summit region about the head-waters of the Tuscarawas and Walhonding rivers is naturally marshy, but during the process of settlement and cultivation its nature has been much modified by drainage, to the detriment of the streams. It is said to be well supplied with springs, however, and in an east-and-west line through Richland and adjoining counties there still stretches an extensive swampy tract.

Drainage areas.

	Square miles.
Licking river	703
Wills creek	815
Walhonding river	2,159
Tuscarawas river	2,547
Muskingum river below junction of Tuscarawas and Walhonding rivers	4,706
Muskingum river at Zanesville, below Licking river	6,565
Muskingum river at McConnelsville	7,178
Muskingum river at mouth	7,740

The average width of the main river is about 500 feet; its waters are hard, and its bed is said to be composed mainly of gravel and ledge rock. The flow is tolerably well sustained in the dry season, but nevertheless falls very low in some years. On the other hand, the river is subject to heavy freshets; but in the lower course, at

least, the banks are of such height that they are seldom overflowed to an important extent, not oftener, it is estimated, than once in 10 years. Rains in the upper basin produce a gradual and sustained effect on the river, while heavy summer showers falling on the steeper slopes of the lower basin sometimes cause sudden and considerable rises at Marietta.

The Ohio canal, ascending, from Cleveland, the valleys of the main and Little Cuyahoga rivers, crosses what is known as the Portage summit, into the basin of the Muskingum river, follows down the course of the Tuscarawas, and afterward that of the main river, to Websport; it then strikes across to the valley of the Licking, which it ascends, and from which it passes over into the basin of the Scioto river. Websport is on the lowest level between the Portage and Licking summits, from each of which there is toward it an uninterrupted descent. There are received therefore into that level, both from the north and from the west, the surplus waters of the canal, which have been supplied to it at various points between the two summits from the streams along its course, and also from reservoirs located on the summits. These surplus waters are discharged into the Muskingum river at Dresden through what is known as the "Muskingum side-cut", a short lateral canal between 2 and 3 miles in length. No accurate data could be obtained as to the amount of water thus discharged, the extent to which the various streams are drawn upon to feed the canal, or the volume of water flowing in the main river and its principal tributaries. When the canal surveys were in progress, nearly sixty years ago, numerous gaugings were made, but were largely confined to the small streams. Since that time, also, this region, once in common with the whole state heavily wooded, has been mainly stripped of its timber, and the character of the streams has without doubt been affected. As nearly as can be ascertained, the tributaries of the Muskingum are now drawn upon for feeding the Ohio canal as follows:

Streams in the Muskingum River basin drawn upon for feeding the Ohio canal.(a)

Name of stream.	Where drawn upon.	Remarks.
Wolf creek	Just below the first lock south of the Portage summit-level.	In 1840 this stream was counted upon to yield, in the driest seasons, 200 or 300 cubic feet of water per minute. Canal crosses by means of a dam.
Tuscarawas river	Clinton, 6 miles from south end of Portage summit-level.	Canal crosses in pool above dam. At lowest stage stream was relied upon for 300 or 400 cubic feet of water per minute.
Meselee creek	Three miles from Clinton	Water received through a feeder 1½ mile long. Stream very constant, formerly yielding at lowest stage about 800 cubic feet per minute.
Mend brook	Three miles above Massillon	A small but constant feeder of about 200 cubic feet per minute. The water received from the above sources, together with that brought from the summit-level, aided by large and numerous springs between Massillon and Bethlehem and in the vicinity of the latter place, supplies the canal to Zoar, in Tuscarawas county, 36 miles from the summit.
Tuscarawas river	Zoar, Tuscarawas county	A short feeder introduces an abundant supply of water, feeding the canal for 21 miles beyond.
Sugar creek	Near Dover	Canal crosses in pool of dam, but, formerly at least, it was not found necessary to draw upon the stream for feeding-purposes.
Tuscarawas river	Half a mile below the mouth of Stillwater creek.	Water received into canal about a mile below Trenton, through a navigable feeder 3¼ miles long, 32 feet wide at water-line, 18 feet wide at bottom, and 4 feet deep. This feeder enters 21 miles below Zoar, and furnishes an abundance of water for the next 30 miles.
Walhonding river	Six miles above Roscoe	Water brought down the Walhonding canal and supplies the main canal to Websport, which is on the lowest level between the Portage and Licking summits.
Licking river	"Narrows of Licking", 10 miles by canal below Newark.	Canal enters pool above dam, and for 2 miles there is slack-water navigation. From this point canal is fed for 17 miles below to Websport.
North fork of Licking river.	Newark	Stream formerly held good for 800 cubic feet per minute in driest seasons, more than sufficient to supply the canal to the "narrows" below.
Raccoon fork	One mile southwest from Newark	At lowest stage was reckoned as only sufficient to supply the level into which it is introduced.

a All the data in this table were taken from the *Fifth Annual Report of the Board of Public Works of the State of Ohio*, rendered January 11, 1842. For access to this and other reports, and for much general information concerning the canals of Ohio, thanks are due to Mr. John B. Gregory, chief engineer of the board of public works.

In addition to the sources of supply above mentioned, this portion of the Ohio canal also receives water from reservoirs on each of the summits. Connected with the Portage summit-level are three small lakes, described in a report of 1842 upon the canal as comprising an aggregate area of 350 acres. One of these—the Summit lake—nearly three-quarters of a mile long, forms part of the canal. The principal supply of water to this summit comes from the upper course of the Tuscarawas, here a small stream, but spoken of in the report just alluded to as remarkable for the uniform quantity of water flowing in it at all seasons of the year, being never less than 1,800 cubic feet per minute.

Although it is not probable that any large reservoirs have been built in Ohio expressly for storing water for hydraulic power, yet their construction is evidently practicable; but there is a question, for the settlement of which little information has been obtained, whether storage of importance would not require too great an outlay to be profitable. In New England, where the storing of water in reservoirs during one-half the year for use during the other half has become so extensive, there are many natural lakes which are taken advantage of and are easily controlled, large tracts of low or swampy land practically worthless for agriculture, the country is well wooded and is underlaid by impervious metamorphic rocks, springs almost everywhere abound, and evaporation is less relatively than in most other parts of the United States. In Ohio, on the other hand, there are few natural lakes of much size. It has been found profitable to drain many of the swamp-lands for purposes of agriculture, the country has been largely denuded of its timber, the hard metamorphic rocks are missing, and strata much more pervious to water supply their place. Springs are abundant in some sections, it is true, but they are very unevenly distributed, in general, and the proportion of rainfall lost in evaporation is considerably larger than in the New England states.

For the benefit of its canal system the state has constructed several large reservoirs, but no data regarding their cost are at hand, except in the single case of the Saint Mary's reservoir, in Mercer county, near the Ohio and Indiana line, covering a surface variously reported at 12,000 and 17,000 acres, and which in one of the canal reports is stated to have cost, in round numbers, $600,000.

On the summit between the Licking and Scioto rivers is what is called the Licking reservoir, which feeds the canal easterly as far as Newark and westerly to the point where the Columbus feeder from the Scioto is received. As originally built, this reservoir extended from west to east nearly 8 miles, with a medium breadth of half a mile, and, when at a level 6 feet above the water-line in the canal, covered an area of nearly 2,500 acres; it was considered capable of furnishing the summit-level and the other levels dependent upon it with water for a period of three months, without any aid from streams, and with these its capacity for supplying the canal was much increased. This, however, was in comparatively early times, when the state was heavily timbered; it has since been found necessary to increase the flowage to about 3,300 acres, and even now the reservoir proves insufficient for the demands made upon it. It was thus described, as first built, perhaps fifty years ago:

The great reservoir on the Licking summit occupies a natural basin, the bottom of which is a tenacious soil composed principally of clay. This basin was surrounded by higher ground, except on the northwestern side, where the ground was low and flat. A large portion of its area was originally occupied by a chain of small lakes and an extensive marsh. Across the low ground on the northwestern side part of the waters of the South fork of the Licking in times of flood flowed into the marsh, and as the floods subsided returned again into that stream. In order to confine the water in this basin an artificial bank of about 4 miles in length, 2 miles of which also forms the towing-path bank of the canal, was raised across the low ground on the northwestern side; and the waters of the South fork, taken from the stream several miles above, are conducted by a feeder of about 6 miles in length on a higher level into the reservoir, near the southwestern end of which the feeder passes over the canal on an aqueduct and falls into the reservoir.

In order to connect the reservoir with the summit-level of the canal a cut nearly 3 miles long was made, having a maximum depth of about 34 feet and involving the excavation of nearly a million cubic yards of earth, which was found to be composed mainly of blue clay and sand, with small pebbles of stone firmly imbedded.

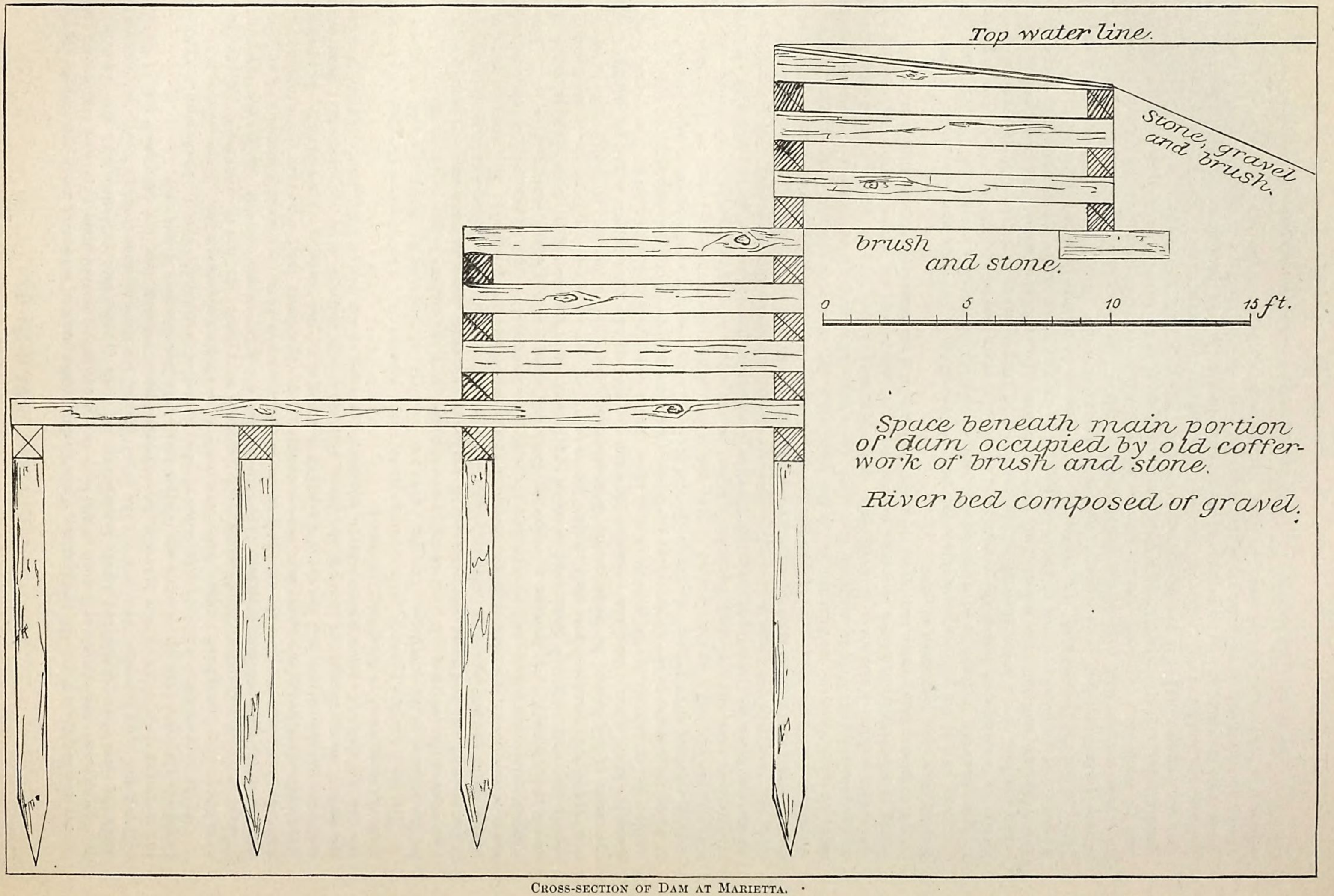
The city of Marietta, which is at the mouth of the Muskingum, had a population of 5,400 in 1880; Harmar, directly across the river, 1,600. Ascending the stream the principal places are the villages of Beverly, 800 inhabitants; Malta, 650; McConnelsville, 1,500; the city of Zanesville, 18,100; Dresden village, 1,200; and Coshocton village, 3,000. In general the basin of this river is well intersected by railroads; the main stream above Zanesville, the Licking, and the Tuscarawas are all followed by railway lines and at the same time command canal navigation, but between Zanesville and the mouth the railroads are distant, most of the way, from 10 to 20 miles on either side, and the adjoining section is more directly dependent upon the river itself for freighting-facilities.

Table showing elevations on the Muskingum river and tributaries.

Locality.	Distance from mouth of Muskingum river.	Elevation of water-surface above mean sea-level.	Fall between points.	Distance between points.	Fall per mile between points.	Authority for elevations.
	Miles.	*Feet.*	*Feet.*	*Miles.*	*Feet.*	
Walhonding river (Black fork of Mohican creek) at Pittsburgh, Fort Wayne, and Chicago Railroad crossing west of Loudonville.	*a* 151	936.54	237.05	60	3.95	Low-water surface by Pittsburgh, Fort Wayne, and Chicago Railroad levels.
Muskingum river at Dresden, low-water surface.	91	699.49				
Tuscarawas river at railroad-crossing 2 miles north of New Philadelphia.	*a* 154	864.48	164.99	63	2.62	Levels of the Cleveland, Tuscarawas Valley, and Wheeling railroad. Low-water surface of stream 291.4 feet above mean surface of lake Erie.
Muskingum river at Dresden, low-water surface.	91	699.49				
Licking river at railroad-crossing, Newark.....	*a* 100	791.00	116.00	25	4.64	Low-water surface by levels of Pittsburgh, Cincinnati, and Saint Louis railroad.
Licking river at mouth	75	675.00				
Muskingum river at Dresden	91	699.49	25.35	16	1.58	Elevations obtained by adding to that at Marietta the fall of the river as given in special report of canal commissioners, January 17, 1828.
Muskingum river at foot of Zanesville dam.....	75	674.14	104.32	75	1.39	
Muskingum river at mouth	0	569.82				Low water in the Ohio at Marietta, as given in report by W. Milnor Roberts, April 21, 1870. (*House Ex. Doc. No. 72, Forty-first Congress, third session.*)

a Distances on the Walhonding, Tuscarawas, and Licking rivers obtained by map measurement, and probably under the truth.

The available water-power of the main river is found chiefly at the dams which were constructed more than forty years ago by the state for creating slack-water navigation. Eleven of these dams were built, extending navigation from the Ohio 91 miles up stream to Dresden, where connection is made through the Muskingum side-cut with the Ohio canal. In extreme low water boats of 3 feet draught can ply on the river, and in an ordinary stage those of 5 feet draught. Several daily lines of steamers run between Marietta and Zanesville, 75 miles above, and weekly round trips are also made between Zanesville and Pittsburgh. The freight on the river is composed mostly of produce and various kinds of merchandise. The shipments down stream are largely made up of wheat, bacon and pork in bulk, and cast iron; those up stream of merchandise, lumber, and bone-dust, and occasionally boats ascend with cargoes of coal and coke. The dams on the Muskingum river are said to have a general similarity in construction, and are crib-work structures resting variously on rock and gravel beds, in the latter case supported,



CROSS-SECTION OF DAM AT MARIETTA.

in part at least, upon piles. In building the Marietta dam, coffer-work of stone and brush was thrown up, directly below which the downstream crib-work of the dam was constructed, resting upon piles and forming an apron to break the force of the overfalling water; the upstream or main crib was then extended back over the coffer-work, utilizing that as its immediate foundation. The ascent around the dams is made through locks and short side-cuts, and averages from 11 to 12 feet between the successive pools, ranging, however, between 8 and 17 feet; below Zanesville the locks built by the state are 175 feet long in the chamber and 36 feet wide.

By the improvements which have been described a total fall of from 100 to 125 feet, and the surplus waters of the river above the demands of lockage, have been rendered available for water-power. These advantages have been utilized, to a moderate extent, continuously since the dams were built. At first the convenient shipping-facilities afforded by the river rendered especially favorable the sites along its course; but with the general introduction of railroads throughout the state the old water-routes of transportation have been largely supplanted, and the lower Muskingum river, being, as we have seen, at some distance from any railway line, is not so attractive to manufacturing-enterprises as it once was, and the use of its power is thought, on the whole, to have declined. At present there are mills at many, though not at all, of the dams; they are chiefly engaged in the manufacture of flour, but there are also reported to be small woolen-mills in successful operation at Beverly and McConnelsville, and at Zanesville there are three wood-working establishments.

The state conveys power to private parties under thirty-year leases. At the end of the time bids are received for the renewal of the privilege. The old lessee has the right of renewing for the same period as before, at the highest *bona fide* bid price. If he does not desire to renew, then the highest bidder as above must take the power at the price offered, and must also purchase all buildings and other appurtenances properly connected with the former use of the privilege, at a price to be fixed by appraisers. There are occasional exceptions to these limited leases, where power had been employed before the state improvements were made. The needs of navigation as regards water must always first be met, and the state also reserves the right to deprive the lessee of water one month in the year, for the purpose of repairing dams and other works, without abatement of rent. The leases specify that water shall be taken over so-called "regulating weirs", which are to be solidly constructed of stone and capped with wood and iron, their crests 6 inches below the surface of water in the pools, or say 6 inches below the crests of the dams. Notwithstanding these directions, there are in fact no regulating weirs in use, at least along the lower river. The rentals charged for water are without any uniformity in rate, little attempt is made to confine lessees to their lawful quantities, and these are in consequence often exceeded. The principle observed in fixing rates seems to have been rather to charge what the lessee could probably afford to pay than to follow any regular schedule of valuation. At Zanesville and Marietta advantage is had of location in cities and of convenient shipping-facilities both by land and by water; power is evidently therefore worth more at those points than at intermediate ones, and the rates charged are higher on the whole, although subject to a wide range. At Beverly we find one lessee paying $60 per annum for 350 cubic feet of water per minute, and another only $100 for 1,200 cubic feet. At Zanesville one lessee is entitled to 625 cubic feet per minute for $83 per annum, while a second pays $800 for 2,200 feet, and a third $500 for 1,100 feet. With very few exceptions, the amounts of water actually used at the different mills are much greater than the lessees are legally entitled to, being in some cases six, eight, and even more than ten times the lawful amount. A few years since, Mr. A. J. Spaulding,(*a*) civil engineer, of Zanesville, was employed by the state to ascertain how much water was really taken under leases at the various points along the canals and the Muskingum improvement. His report showed that upon the latter, under a total of eighteen leases in which water had been conveyed in cubic feet per minute, the aggregate amount thus conveyed was, in round numbers, 23,000 cubic feet, while that used, judging in most cases from the wheel-ratings, was 97,000 cubic feet, or more than four times as great.

Only two of the privileges on this river were visited—those at Marietta and Zanesville. At Marietta the river is about 600 feet wide, and a quarter of a mile or so from the mouth is encountered the first dam. The old lock is on the west side, but at the opposite end of the dam there was being built in 1882–'83 by the government a fine new lock of cut stone, through which steamers and barges employed on the Ohio may ascend to the pool above the dam, and find there a harbor of refuge in winter. The pool is of ample dimensions, having a length of 5½ miles and an average width of about 500 feet. The surplus water at the dam is utilized in part both on the Marietta and the Harmar side. On the former, water is taken from above the dam and carried in a circuitous open channel to Rollston, Hall, & Co.'s flouring-mill, a short distance below. This is a large and fine mill, with elevator, and has an ordinary daily capacity for producing 250 barrels of flour, being furnished with seven pairs of burr-stones and five double sets of rollers. On the Harmar side water is conveyed directly down the bank in an underground wooden trunk, and utilized at Dircks & Co.'s flouring-mill, capacity 150 barrels. With a full pond the fall at the dam is in the neighborhood of 10 feet in ordinary low water. Rollston, Hall, & Co. estimate a loss of about a foot of fall in their race, and place their maximum head at 9 feet, and the average at 6½ or 7. The privilege is subject to back-water from the Ohio, and for an average of about thirty days in the year the mills are deprived altogether of water-power, and must rely upon steam, while for a total of three months the head is seriously affected, ranging down all the way between 6 feet and zero. In June, 1881, there was a depth on the dam of 20.7 feet, due to Ohio back-

a Mr. Spaulding and Mr. William Smith, of Harmar, kindly furnished much information concerning this river.

water, and the same February 23, 1882. There are times during very low water when the supply is somewhat short, and the pool even becomes drawn down a foot or two; but for nearly all the year there is a wastage on the dam, and consequently an available surplus of power. It was stated that when the new government lock should be completed water would be taken in an open cut directly down the Marietta bank to Rollston, Hall, & Co.'s mill instead of following the present roundabout course, and that there would thus be offered sites for more mills. On the Harmar side, also, the state reserves the right to tap the trunk leading to Dircks & Co.'s mill, and there is abundant room for building.

At Zanesville the river is crossed by dam No. 2, below which rocky shoals stretch for some distance. The dam is provided with an apron in two successive pitches, and has abutments rising 17 feet above its crest; but it is said that this height is none too great, and that, even as it is, ice is sometimes forced up on to the masonry. Navigation is accommodated through a side-cut, which from the pool bears well off into the city and enters the river again considerably farther down stream, below the dam and shoals. From this side-cut the mills on the east bank are also supplied with water for power. The full fall practically available is perhaps from 14 to 16 feet, but is not realized by all the mills, and in times of very low water is reduced, and during freshets is liable to be almost or even entirely destroyed. Power is utilized along the side-cut at Cassell & Co.'s flouring-mill, ordinary production 150 barrels per day; at Grant's flouring-mill, 100 barrels capacity; at the Muskingum Coffin Company's works, employing 30 hands; and at Gay Brothers & Silvey's furniture factory, employing 30 hands. On the west side of the river water is drawn from the pool through an independent race and brought to Drone & Co.'s flouring-mill, capacity 250 barrels per day; and some power is also used in Burrow & Ball's furniture works. The lessees recognize no priority of right among themselves in case of scarcity of water, and at such a time each endeavors to supply his wants without regard to the others; disputes are frequent, and the state authorities sometimes have difficulty in shutting off the mills so as to maintain a sufficient depth of water for navigation. In a low stage of river the lessees are sometimes entirely deprived of water-power for a period of perhaps three weeks, usually in the latter part of July and early in August. Late in January the river generally rises, the ice breaks up and runs out, and for from ten days to two weeks the mills are stopped by high water, and for a still longer time suffer more or less reduction of head.

Estimate of power at the various state dams on the Muskingum river.

Locality	Distance from mouth of river.	Drainage area.	Fall, pool to pool, as given in state report of 1842. (*a*)	Flow per second, mean for the 24 hours, available 10 months in an average year. (*b*)	Corresponding theoretical horse-power. (*c*)	Amount of water leased, as stated in report made a few years since by Mr. A. J. Spaulding.
	Miles.	*Sq. miles.*	*Feet.*	*Cubic feet.*		
Dam No. 1, near Simm's creek, 6 miles below Dresden	85	5,795	8	490	445	35.4 cubic feet per second.
Dam No. 2, Zanesville	75	5,862	17	500	966	120.4 cubic feet per second.
Dam No. 3, Taylorsville and Duncan's Falls	65	6,922	13	590	870	Sufficient for 15 runs of stones.
Dam No. 4, Rokeby and Eagleport	55	7,123	9	600	613	
Dam No. 5, McConnelsvile and Malta	48	7,178	9½	610	658	Sufficient for 10 runs of stones.
Dam No. 6, Windsor	38	7,219	11	610	762	26.7 cubic feet per second.
Dam No. 7, Luke's chute	33	7,233	12	610	831	
Dam No. 8, Beverly and Waterford	23	7,625	11	650	812	101.7 cubic feet per second.
Dam No. 9, Lowell	12	7,704	12	650	886	
Dam No. 10, Devoll's	5	7,723	10½	660	787	
Dam No. 11, Marietta and Harmar	0	7,740	12	660	900	100 cubic feet per second.
Total			125		8,530	

a Lift of locks at low water. The figures given may be considered the limits of available fall, and at some of the dams are never fully realized by the mills as located.

b Liable to reduction for lockage, for which, and the accompanying waste, the maximum demand should not probably exceed 10 cubic feet per second per foot of lockage, except at the large new government lock at Marietta, which has been designed of a capacity 3 or 4 times as great as that of the locks above, and which will require a correspondingly large supply of water.

c In the ten months assumed, however, the power is liable to be completely cut off by backwater for a period ranging, in different parts of the river, from ten days to a month, the latter at the mouth; and to be more or less interrupted through reduction of head for a longer time, reaching at Marietta two months in addition to the one month of complete stoppage.

NOTE.—The effective horse-power may be reckoned at from 60 to 80 per cent. of the theoretical. According to the enumerator's returns there was in use in 1880 a total of 1,100–1,200 rated horse-power of wheels on the entire main river.

TRIBUTARIES OF THE MUSKINGUM RIVER.

The Tuscarawas river includes within its 2,547 square miles of drainage area the greater portions of the counties of Tuscarawas, Harrison, Carroll, and Stark, and lesser proportions of several other counties adjoining these. From the mouth to above New Philadelphia the stream winds through alluvial bottoms, now and then approaching a bluff, which gives it for a time a high bank, but in general one or both banks are low, and in places are subject to annual overflow. The bottoms are fertile and are largely cultivated in corn. Beyond them is a rise to what appear from the valley as ranges of hills, but which are in reality only the swells in the general level of the

country, below which the valley of the stream is depressed. Beginning at a point 3 miles above New Philadelphia, for some 7 miles above the river runs over clay and sandstone rock, and its banks are of good height. Elsewhere the bed of the stream is described as gravelly, the coarser material on the shoals. These shoals are short and occur only occasionally; they are separated by long pools, and the general descent of the stream is slight. The owner of the dam at New Philadelphia claims that it sets back the river for 6 miles. The Tuscarawas is tolerably full and well sustained in volume, and is less rapid in fluctuations than the Walhonding, the other principal affluent of the Muskingum river. In Tuscarawas county the soil is clayey, and hence not very receptive of water, though sufficiently so for all purposes of good farming. Before the general settlement of this district there was much swamp-land in the bottoms and elsewhere, which drained slowly into the stream; but since the country has been cleared surface-waters run off much more readily. In addition to being well adapted to farming, the section tributary to this river possesses valuable beds of coal and of "black-band" ore.

Half a dozen miles below New Philadelphia there is a state feeder-dam across the main stream and a tributary, and a private dam some distance above. From the latter, water is conveyed down to a small mill located near the feeder and discharged after use into that channel. At New Philadelphia, a village of 3,000 inhabitants, Mr. A. Beyer has a fine mill with a capacity for manufacturing 250 barrels of flour per day. The dam, which was built about 1870, is distant a mile up stream and rests on a gravel bed. The latter has been artificially added to, however, by a very large amount of loose stone, estimated at many thousand perches, thrown in during previous futile attempts to maintain a dam. The present structure is 350 feet long, 7 or 8 feet high, and is of stone built up in terraces and bound with timber and iron. Water passes down the left bank in a race to the mill, where a fall of 9 feet is realized. The mill contains 17 sets of rollers, for running which there is claimed to be always more than sufficient power. Mr. Beyer estimates the privilege as suited to a mill of 500 barrels daily capacity during ten months of the year. The principal trouble is from backwater, though that difficulty is not regarded as very serious. At this locality advantage is had of the waters of Conotten and Sugar creeks, which enter the Tuscarawas between New Philadelphia and the Zoar feeder-dam, several miles above. At the latter point power is returned as utilized by several mills and shops. There are flouring-mills also at intervals above well up toward the head-waters.

The Walhonding river is the second important tributary of the Muskingum, its drainage basin containing 2,159 square miles and inclosing, almost entire, the counties of Knox, Richland, Ashland, and Holmes, and covering considerable portions of Coshocton, Wayne, and Morrow. In the vicinity of Coshocton village, where they unite, the Walhonding and Tuscarawas flow through a wide flat valley succeeded by rolling country. Each stream is 250 or 275 feet wide between banks, the latter low. Heavy freshet-rises occur, the oscillations at Coshocton reaching 15 or 16, and even, in extreme cases, from 20 to 22 feet. The Walhonding begins to subside first, and after a general storm invariably reaches its flood stage from twenty-four to forty hours in advance of the Tuscarawas. The availability of the lower river for water-power is chiefly in connection with the Walhonding canal. This leaves the Ohio canal at Roscoe, at the mouth of the river, and ascending along the south bank for 6 miles crosses in the pool of a low dam 3 or 4 feet high, to the north bank, which it then follows for 17½ miles to Cavallo, where there is a second dam a few feet in height. By this dam slack-water is extended 1½ mile to the village of Rochester. The total descent from this pool to the level of the Ohio canal at Roscoe is 90 feet, which is accomplished by 11 locks of cut-stone masonry.

The Walhonding canal was designed to serve both for traffic and as a feeder to the Ohio canal. Except in one or two years the navigation is said never to have been large enough to make it profitable, and recently the 17 or 18 miles above the lower dam was sold by the state to the Mount Vernon, Coshocton, and Wheeling Railroad Company, a new enterprise, and will no longer be used for boats. The company considers that the canal offers a good water-power, which it intends to maintain and lease. Mills would naturally be located at the locks, although there are opportunities for discharging directly into the river; but it is of course more desireable that the water should be used over and over. A right is also owned by this company to construct its track on the canal-bank for the 6 miles from the lower dam to Roscoe, but it does not own that portion of the canal, and the latter is nominally to be kept open by the state for navigation, and more especially as a feeder.

At Roscoe the Walhonding canal descends by three locks into the Ohio canal, and from the upper level water is drawn to supply the large flouring-mill of Barney, DeMoss, & Co., and a small woolen-mill, both discharging under a head of 24 feet into the Ohio canal. The flouring-mill has a capacity of 200 barrels per day, and uses about 125 horse-power. The power is stated to be very constant, with no interruptions from ice or low water. It is estimated that if the canal is maintained in proper condition there will be a uniform flow through this portion of at least 7,000 cubic feet per minute. It has been allowed to silt up somewhat, however, and needs dredging. From Cavallo to the mouth of the river the only use of power, aside from that just described, is by a flouring-mill at Walhonding village, some 18 miles up stream, and by a custom-mill at Warsaw, 8 miles from Roscoe, both mills of fair size. Assuming that an average flow of 100 cubic feet per second can be maintained throughout the length of the canal, the available power will be in the neighborhood of 1,000 theoretical, or say from 600 to 800 effective, horse-power.

The Licking river.—In Newark township, near the center of Licking county, three branches, known respectively as the North, Middle or Raccoon, and South forks, unite to form the main Licking river, which then pursues an easterly course into, and nearly to the center of, Muskingum county, passing through a distance of about 25 miles, with a descent of 116 feet, and entering the Muskingum river at Zanesville immediately below the state dam. The country

bordering the main river, at least, is well supplied with springs, and the volume of flow is said to be very well maintained; nevertheless it is not so well maintained as it was before the country was cleared up, and men long acquainted with this section are positive in their statements that there has been in forty years a decided shrinkage in the streams, forcing the abandonment of many small powers. In order to feed the Ohio canal the Raccoon fork is drawn upon 1 mile to the southwest of Newark, the North fork contributes a supply through a feeder at that city, and some 10 miles down stream a state dam controls the entire flow of the main river. The great Licking reservoir of over 3,000 acres, on the summit between this river and the Scioto, has already been described. The stream runs smoothly in general, with a moderate current. The banks along the lower course are of good height, and are but little overflowed in freshets.

Close by the mouth Messrs. Hook Brothers & Aston have a flouring-mill with 11 runs of stones and a capacity for producing 175 barrels of flour per day. The dam was built twenty years or more ago, and is a framed structure 300 feet long by about 8 feet in height. It rests upon a bed of limestone between 2 and 3 feet thick, which is said to extend up the stream and underneath which is found slate rock. A fall of 7½ feet is obtained at the mill, and 128 horse-power is in use. During three or four months in the year there is more or less shortage of water. The pond extends about a mile up from the dam, but is insufficient for storing the night flow unless in an exceedingly dry season; at all other times, with the mill stopped there is certain to be a wastage over the dam before morning.

About 4 miles above Zanesville are what are known as the "Falls of Licking". The river valley is here narrow, and the stream itself descends in rapids for a distance of a quarter of a mile, accomplishing a descent which was found by pocket-level to be in the neighborhood of 15 feet. The bed is rocky, and the principal fall occurs near the foot of the rapids, where the strata dip considerably to the south. At the head of the rapids there is said to be a pool 12 or 15 feet deep; the rocks thus form a natural dam, and it is considered that the privilege could be improved by simply cutting a channel down from this pool. Above the rapids there is an alluvial flat where the banks are low, but thence down past the falls they are high and composed in part of soil and in part of rock. The river is here perhaps 250 or 300 feet wide. If it were desired, a dam could be thrown across near the head of the rapids and water brought down the left bank, and a fine location found for a mill near the foot of the falls. Probably no objection would be raised against the building of a dam of moderate height on the score of aggravating the danger of submergence to land above; on the other hand, it would check the current of the stream and prevent a washing of the banks which now goes on, and it is said that parties have even petitioned to be allowed to construct a dam for that purpose alone. The privilege belongs to the estate of the late A. H. Brown, of Zanesville. It was formerly in use to some extent, but no power is now employed, except in an insignificant way by a little clay-mill having a short wing-dam.

Two or three miles above, at Claypool, there is a flouring-mill, and there was also said to be a saw-mill at the Licking feeder-dam, but no other power was mentioned as being in use on the main river. The various forks in Licking county furnish power to a number of small flouring-mills, but are not regarded as of especial value. Their beds are gravelly, the banks are composed of gravel and loam, and it is found difficult to maintain tight dams. The North fork is at Newark about 80 feet wide.

Wills creek enters the Muskingum river from the east about 8 miles south of Coshocton. It drains the greater part of Guernsey county, together with portions of several surrounding counties, its basin embracing 815 square miles. A number of small flouring- and saw-mills are found on the tributaries, as well as on the main stream, but the latter is extremely crooked and sluggish, with an average descent, as stated by Professor Orton, not exceeding a foot per mile for nearly its whole length, and is of little importance.

Table of utilized power on the Muskingum river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Muskingum river	Ohio river	Ohio	Washington	Flouring and grist	2	7–9	190±	60	Marietta and Harmar.
Do	do	do	do	do	2	12	55		Adams.
Do	do	do	do	Saw	1		20		
Do	do	do	do	Agricultural implements	1	9	30		Beverly.
Do	do	do	do	Flouring and grist	3		105		
Do	do	do	do	Woolen	2		55		
Do	do	do	Morgan	Flouring and grist	2	8–11	130		
Do	do	do	Muskingum	do	2	9	48		Harrison and Wayne.
Do	do	do	do	do	3	14–16	482		Zanesville.
Do	do	do	do	Furniture	2		10+		
Do	do	do	do	Coffins and burial-cases	1		40		
Sundry small tributaries.	Muskingum river.	do	Washington	Flouring and grist	3	27	99		
Do	do	do	do	Saw	3	21	60		
472									

Table of utilized power on the Muskingum river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Sundry small tributaries.	Muskingum river.	Ohio	Noble	Flouring and grist	1	6	8	.....	
Do	do	do	Morgan	do	3	32	65	.....	
Do	do	do	Perry	do	2	12½	60	35	
Do	do	do	Muskingum	do	6	48	142	.....	
Do	do	do	do	Saw	5	42½	75	.....	
Do	do	do	Coshocton	Flouring and grist	2	13	46	.....	
Tuscarawas river	do	do	Tuscarawas	do	1	5	26	.....	Warwick.
Do	do	do	do	do	1	9	150	.....	New Philadelphia.
Do	do	do	do	do	2	.....	105	.....	
Do	do	do	do	Lumber, planed	1	5	14	.....	Zoar.
Do	do	do	do	Machinery	1		10	.....	
Do	do	do	do	Saw	1		15	.....	
Do	do	do	do	Woolen	1		24	.....	
Do	do	do	Summit	Flouring and grist	4	63	180	.....	
Tributaries	Tuscarawas river.	do	Medina	do	3	63	56	68	
Do	do	do	do	Sashes, doors, and blinds	1	16	30	30	
Do	do	do	do	Saw	1	16	30	30	
Do	do	do	Summit	Flouring and grist	1	10	24	25	
Do	do	do	Stark	do	15	179½	673	200	
Do	do	do	do	Saw	4	43	94	.....	
Do	do	do	do	Baskets, rattan- and willow-ware.	1	8	16	.....	
Do	do	do	Wayne	Flouring and grist	3	53	71	25	
Do	do	do	do	Woolen	1	15	15	.....	
Do	do	do	Holmes	Flouring and grist	1	12	10	.....	
Do	do	do	do	Saw	2	34	35	.....	
Do	do	do	Tuscarawas	do	1	12½	40	.....	
Do	do	do	do	Flouring and grist	10	83	309	245	
Do	do	do	Columbiana	do	1	16	40	60	
Do	do	do	Carroll	do	5	39	105	.....	
Do	do	do	Harrison	do	4	31½	87	35	
Do	do	do	Belmont	do	1	16	15	.....	
Do	do	do	Coshocton	do	1	7	20	.....	
Walhonding river	Muskingum river.	do	do	do	1	14+	64+	.....	
Do	Do	do	Knox	Saw	1	7	20	.....	
Tributaries	Walhonding river.	do	Wayne	Flouring and grist	11	211	247	157	
Do	do	do	do	Machinery	1	3	12	12	
Do	do	do	do	Saw	1	20	24	.....	
Do	do	do	do	Woolen	2	14+	31	.....	
Do	do	do	Ashland	do	1	27	8	.....	
Do	do	do	do	Saw	2	14	27	.....	
Do	do	do	do	Furniture	1	16	4	.....	
Do	do	do	do	Flouring and grist	9	120	203	164	
Do	do	do	Richland	do	18	239½	382	.....	
Do	do	do	do	Furniture	1	4	10	18	
Do	do	do	do	Saw	9	105	166	.....	
Do	do	do	do	Woolen	3	25½	47	10	
Do	do	do	Morrow	Flouring and grist	3	29½	47	.....	
Do	do	do	do	Saw	1	16	20	.....	
Do	do	do	Knox	do	4	10	74	.....	
Do	do	do	do	Flouring and grist	15	160+	452	45	
Do	do	do	Holmes	do	12	175	270	85	
Do	do	do	do	Saw	2	13½	45	.....	
Do	do	do	do	Woolen	5	50+	68	10	
Do	do	do	Coshocton	Flouring and grist	2	16	40	.....	
Do	do	do	do	Saw	2	5+	18	.....	
Licking river and tributaries.	Muskingum river.	do	Licking	Flouring and grist	9	105½	199	96	
Do	do	do	Muskingum	do	3	19	178	.....	
Wills creek and tributaries.	do	do	do	do	1	7	45	.....	
Do	do	do	Coshocton	do	2	14	50	.....	
Do	do	do	do	Saw	1	7	25	.....	
Do	do	do	Guernsey	do	7	50+	200	68	
Do	do	do	do	Flouring and grist	7	56	168	30	
Do	do	do	Noble	Saw	1	6	8	.....	

THE LITTLE KANAWHA RIVER.

Drainage areas.

	Square miles.
West fork of Little Kanawha	210
Hughes river, branch of Little Kanawha	660
Little Kanawha at Burning Springs	1,190
Little Kanawha at mouth	2,290

The sources of this river are in the southern part of Upshur county, West Virginia, whence it takes a northwesterly direction across the counties of Branton, Gilmer, Calhoun, Wirt, and Wood, to Parkersburg, where it empties into the Ohio. In an air-line the distance from the extreme head to the mouth is about 85 miles, but this is increased to 160 miles or more when we follow the meanderings of the stream. The Little Kanawha river has not much value for power, except, as hereafter to be seen, at the navigation company's dams. In the more important part of its course the fall is small, averaging only about 1½ foot per mile for 130 miles above the mouth. About the year 1874 a survey nearly to the head-waters was made by government engineers, and the fall found as below:

Table showing the fall in the Little Kanawha river.

Locality.	Distance above mouth.	Elevation of water-surface above low tide in ocean.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Bulltown	130.75	762.3	87.75	147.5	1.68
Mouth of Spring creek	43.00	614.8	43.00	52.0	1.21
Mouth of Little Kanawha river	0.00	*a* 562.8			

a Elevation of low water in the Ohio river by W. Milnor Roberts' report of 1870, 563.69 feet.

The Little Kanawha Navigation Company has four locks and dams on the lower river for slack-water navigation. The dams are uniformly about 16 feet high above foundation, and the locks have each a lift of 12 feet at an ordinary low stage of river. Three boats ply regularly on the stream, and carry on a very considerable amount of traffic, which is increasing. Since the organization of the navigation company its receipts from tolls have advanced from about $9,000 to nearly $30,000 per year. Four-foot slack-water navigation is maintained from the mouth to Burning Springs, 40 miles above, and in 1882 the national government was building a dam still above, which was to extend slack-water somewhat farther.

At the second dam from the mouth the construction of a small grist-mill was begun, but not completed, and at the fourth dam a 2-run grist-mill is steadily in operation, obtaining its power at a rental of $150 per annum. Farther than this the writer could gain no knowledge of any utilization of the stream for power. The navigation company is anxious to have the surplus power at its dams put to use, and has made efforts to secure such a result, but with very little success. Abundance of water could be relied upon for about nine months in the year, but there seems to be scarcely any demand for hydraulic power in this section. The owners of the saw-mills find it to their advantage to burn up waste and run by steam, and there is otherwise but an insignificant amount of milling. This section is naturally fertile, but in years past the land has been drawn upon heavily for tobacco culture without being enriched in return, and has thus become badly run down. It is naturally a blue-grass region and finely adapted to grazing, but stock-raising is carried on only to a very moderate extent, though it is increasing. As for wheat, there actually is not enough raised for the local supply, and flour has even to be shipped up the river. If a farmer wants wheat or corn ground, it is only a sack or two at a time; none is ground for feeding stock, and there evidently can be but little business for flouring- and grist-mills.

The great industry along the Little Kanawha is lumbering. Poplar is the prevailing timber found, and the principal operations are in that variety, though there are also considerable proportions growing of oak, walnut, and yellow pine. The logs are cut all over the surrounding country, from 50 to 175 miles above the mouth of the river, floated down stream in rafts, usually about 120 feet long by from 20 to 24 feet wide, sawed up in mills scattered along the banks, and made into lumber, staves, and cross-ties. There are three large saw-mills at Elizabeth, and numerous others toward the mouth, and at Parkersburg, which is an active place of about 6,600 inhabitants. For a few miles above the mouth the river is followed by the Baltimore and Ohio railroad, but nowhere else is the main stream directly accessible by rail.

Toward Parkersburg the valley is wide and the river runs between banks of fair height, which are succeeded by comparatively level alluvial land. Far up the stream the banks are said to be alluvial, but the bed is in the main composed of sandstone rock, which is rather soft, so that it is sometimes torn up in large blocks by the overfalling water at the dams, and especially by drift coming over them. Its distribution is very peculiar. Though occurring generally in the bed of the stream it seldom extends clear across, but runs out, sometimes from one bank

and sometimes from the other, perhaps nearly or quite to the opposite bank, and then suddenly drops away. Thus the navigation company's dam No. 1 rests upon rock, while the lock had to be supported upon piling; and it is stated that a rock foundation was found also for the new government dam and for the river-wall of the accompanying lock, but that at the site of the shore-wall borings to a depth of 50 feet failed to strike any rock. It seems probable that the river once ran in a deep channel, somewhat different in course from the present one, and that the old channel has been filled and the river forced over upon what were at some time its banks.

In common with most streams in this section the Little Kanawha is subject to great fluctuations in volume. It rises very rapidly, and apparently with slight provocation. A rise of a foot an hour is not uncommon, and Mr. L. B. Dellicker, of the navigation company, from whom most of the information presented regarding this river was obtained, has known a rise of 28 feet in twenty-four hours. The country drained is characterized by steep slopes, or, as was described, "is all on edge", so that rains are quickly shed into the creeks and small streams. Again, the slope of the river is small, as we have already seen, its channel is very winding, and it is unable to carry off the floods of water as rapidly as they are received. According to a rough measurement on the map of the government survey, the distance from Bulltown to the mouth was found to be by general course about 72 miles, against 131 miles by river.

On the other hand, the volume runs very low in the dry season, and often it is only by the very closest economy that the navigation company can command enough water for lockage purposes. In the summer and autumn of 1881 there was no waste over the dams for three months. It is difficult to account for such a state of things. Evaporation is undoubtedly large, but the chief trouble seems to lie in a deficiency of good springs. The soil throughout this section is deep, and is underlaid by porous sandstone rock. It was stated that up the Little Kanawha valley oil-wells have been sunk many hundreds of feet, nearly all of the way through rock, without encountering any water whatever. It seems probable that, while an important part of the rainfall drains off at once, considerable is absorbed by the deep soil and afterward evaporated from the surface, and much percolates to depths too great to allow of its reaching the water-courses.

Table of utilized power on the Little Kanawha river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.
						Feet.	*H. P.*	*H. P.*
Little Kanawha river	Ohio river	West Virginia	Wirt	Flouring and grist	1	10	30	.....
Do	do	do	Gilmer	do	1	4	15	.....
Do	do	do	do	do	1	5½	20	.....
Do	do	do	do	Saw	1		20	.....
Do	do	do	Braxton	Flouring and grist	1	15	20	.....
Do	do	do	Upshur	do	1	13	30	.....
Do	do	do	do	Saw	1	12	12	.....
Hughes river and tributaries	Little Kanawha river	do	Wirt	do	1	6	15	.....
Do	do	do	do	Flouring and grist	1		30	.....
Do	do	do	Ritchie	do	9	58	215	.....
All other tributaries	do	do	Wood	do	1	6	16	.....
Do	do	do	Wirt	do	1	7	8	.....
Do	do	do	Gilmer	do	2	9	26	16
Do	do	do	Roane	do	4	24	40	.....
Do	do	do	Braxton	do	1	7	12	.....

THE SCIOTO RIVER.

This river, which receives the drainage from 6,400 square miles of territory, has its source in western Ohio, in the county of Auglaize. The surrounding region is the most elevated in the state, the greatest altitude, 1,544 feet,(*a*) being reached within 3 miles of the village of Bellefontaine, or in the neighborhood of 20 miles to the southeastward from the source of the Scioto. To the north are the basins of the Maumee and Sandusky rivers, flowing into lake Erie. In a report made more than 50 years ago by the Hon. John Geddes, the country at the head-waters of the Scioto and Sandusky was described as extremely unfavorable to the formation of durable streams, the soil being of such a character as to shed water freely and to give great unevenness in flow to the brooks and creeks. From its origin in the eastern part of Auglaize county the course of the river we are considering is easterly for about 40 miles, through the counties of Hardin and Marion; in the latter the direction of flow changes

a According to Professor Edward Orton, of Columbus, who kindly furnished much general information concerning the streams and topography of Ohio.

to southerly, and remains so until the Ohio is joined at Portsmouth, the river having in the mean time traversed successively the counties of Delaware, Franklin, Pickaway, Ross, Pike, and Scioto. By general course the length of the river is 170 miles; following the bends with tolerable closeness on the map, the distance from source to mouth is about 210 miles, and even this is probably less than the true distance by water. Assuming the elevation at the extreme head-waters of the river to be as great as 1,400 feet, the total fall thence to the mouth may be stated approximately as lying between 900 and 1,000 feet. From a point southwest of Marion the descent to Portsmouth is a little over 430 feet, the average slope being about 5 feet per mile to Columbus, and the remainder of the way about 2 feet per mile.

Table showing the fall in the Scioto river.

Locality.	Distance from mouth.	Elevation of water-surface above mean sea-level.	Fall between points.	Distance between points.	Fall per mile between points.	Authority for elevations.
	Miles.	*Feet.*	*Feet.*	*Miles.*	*Feet.*	
Extreme source of river	210	1,400±				Estimated roughly.
			500±	58	(8-9)±	
Crossing by New York, Pennsylvania, and Ohio railroad at Green Camp, southwest of Marion.	152	900				Water-surface by elevations of the New York, Pennsylvania, and Ohio railroad.
			207½	42	4.94	
Columbus, crest of state dam	110	692½				Elevation obtained by adding to level of low water in the Ohio river 225 feet fall, as given in state canal report of 1842.
			225	110	2.05	
Mouth of river, low water in the Ohio	0	467½				Exact elevation given as 467.526 feet in report of April, 1870, by W. Milnor Roberts.

The basin of the Scioto is a good farming section, and is intersected in various directions by railroad lines, most of which converge at Columbus, a fine city of 50,000 inhabitants. The other principal points on the immediate course of the river are the cities of Portsmouth and Chillicothe, each with a population of about 11,000, and Circleville with 6,000. The upper river, as far as to Delaware county, lies in the drift formation, in which the banks are ill-defined and the valley is flat. Next it enters upon the region of Devonian limestone, and the valley becomes of a rocky-character, and so continues nearly to Columbus. This formation is succeeded by the Devonian black shale, which has been widely eroded and the space occupied by drift. From Columbus to the southern boundary of Pickaway county the river runs through a broad productive valley ranging from 3 to 5 miles in width in general, but spreading out in the "Pickaway plains" much wider and very flat. The valley lands are gravelly in character, said to be usually worth from $100 to $150 per acre, and are mainly cultivated in corn. The uplands are composed of rock covered with a sandy or clayey soil, and are devoted chiefly to wheat and grass. Below Pickaway county the river traverses the region of Waverly sandstone, walls of which, often obscured by slopes of disintegrated material, are to be found on either side of a broad valley, which is to a considerable extent subject to inundation by the Scioto and by backwater from the Ohio river. Three successive bottoms are here to be distinguished: The first, or lowest, is overflowed by every high flood; the second, by extreme freshets; while the third is 50 or 60 feet above low water, and beyond danger of submergence. Along the lower Scioto the bottom-lands yield splendid crops, mainly of corn, but the uplands are of much poorer character, are occupied by a far less thrifty class of farmers, and show but few important villages. There is a large amount of timber still standing in southern Ohio, and in the lower Scioto basin and vicinity a great many hoop-poles and barrel-staves are made and much tan-bark is stripped. The principal variety of timber is said to be oak, though it has largely been cut away, and there is also some poplar and pitch-pine.

In its downward course the Scioto receives at Columbus its first large tributary, the *Olentangy*, which joins it from the north and drains 547 square miles. Below Columbus the principal affluent entering from the east is *Big Walnut creek*, while from the west come *Darby*, *Deer*, and *Paint creeks*, the drainage areas of which are given elsewhere. These streams and various other tributaries of the Scioto are utilized to a much greater extent than the main river for water-power, being more easily controlled and carrying sufficient water ordinarily for the demands of the small flouring- and saw-mills located upon them. Above Columbus, in Franklin and Delaware counties, there are a number of flouring-mills on the Scioto itself, but from that city down the river is not utilized for power, so far as ascertained, at any point. Nor does this portion seem to be, as a whole, at all well suited to such employment. The bed is generally gravelly, the banks are low, and at many points protected against inundation only by means of levees; the course is very winding, the flow smooth, with scarcely a ripple, and, as we have already seen, the average descent is small, not exceeding about 2 feet per mile. High freshets occur in spring and early summer, with an extreme rise in the lower river, from Waverly to the mouth, of from 20 to 21 feet above low water. The mean annual rainfall on the entire basin of this river is approximately 38 inches, distributed as follows: 10 inches in spring, 11½ in summer, 8 in autumn, and 8½ in winter. About the year 1823 or 1824, when surveys were in progress for the Ohio canals, measurements were made of the low-water flow in various streams, among others the Scioto. The discharge of this stream at Columbus was found to be 1,500 cubic feet per minute, or 25 cubic feet per second, and at the mouth of Deer creek, about 10 miles north of Chillicothe, was estimated to be 4,000 cubic feet

per minute, equivalent to 66 cubic feet per second.(*a*) Supposing, as is probable, that the measurement at Columbus was made below the mouth of the Olentangy, where the tributary drainage area amounts to 1,686 square miles, the discharge noted corresponded to an average of only 0.015 cubic foot per second per square mile, while that assumed at the mouth of Deer creek was at about the same rate, or say 0.017 cubic foot per second to the square mile. The rate of flow thus determined is remarkably small, and is even difficult to accept as correct; but it is evident that in times of severe drought the country at the head-waters of this river affords but a scanty supply of water; in fact it was stated in the canal commissioners' report of 1824 that "the Scioto, in a very dry season, above the mouth of Rush creek (Marion county) exhausts by evaporation and absorption nearly all the waters which it receives". No recent measurements of the volume of this river were learned of, but it is improbable that the extreme low-water rate of discharge has materially increased above what it was sixty years ago.

Including the one at Columbus there are three dams on the Scioto from that city to the mouth of the river, all owned by the state and utilized in feeding the Ohio canal. This canal descends westerly from Licking summit, passing down the valley of Little Walnut creek, from which, as well as from Roger's run and Black Lick creek, it receives small supplies of water; and then, as it approaches the course of the Scioto it crosses to the valley of Big Walnut creek, and at Lockbourne is joined by the Columbus feeder. This feeder is 11¾ miles long, and is navigable. It opens out from a pool formed at Columbus by a dam across the Scioto, and descends on the east side of that river to a junction with the main canal, just before reaching which it crosses Big Walnut creek in the slack-water of a dam, thus commanding also the flow of that stream. From Lockbourne the main canal runs southerly on the east side of the Scioto, crossing Little Walnut creek again near its mouth in the pool of a dam and rendering the stream again tributary as a feeder. At Circleville, in Pickaway county, it crosses on an aqueduct to the west side of the Scioto, and 2 miles below the city receives water from the river through a short feeder. The latter opens from the slack-water created by a dam described as 400 feet long, 7 feet high, and constructed of piles. Six miles below Chillicothe still another dam across the Scioto, of about the same height as that at Circleville, diverts into the canal water sufficient to meet the demands of navigation thence to the Ohio.

Drainage areas of the Scioto river and tributaries.

	Square miles.
Olentangy river at mouth (Columbus)	547
Big Walnut creek at mouth	513
Darby creek at mouth	592
Deer creek at mouth	423
North fork of Paint creek	236
Main fork of Paint creek above junction with North fork	828
Paint creek at mouth	1,083
Scioto river at southern boundary of Marion county	628
Scioto river at Columbus, above junction with Olentangy river	1,139
Scioto river at Columbus, below junction with Olentangy river	1,686
Scioto river at Circleville, below Darby creek	3,275
Scioto river at Chillicothe	3,923
Scioto river at mouth	6,400

Table of utilized power on the Scioto river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.
						Feet.	*H. P.*	*H. P.*
Scioto river	Ohio river	Ohio	Franklin	Flouring and grist	5	33½	129	.....
Do	do	do	Delaware	do	3	20½	73	.....
Do	do	do	do	Saw	2	11	45	.....
Tributaries	Scioto river	do	Morrow	Flouring and grist	5	68½	149	25
Do	do	do	Marion	do	2	15½	66	80
Do	do	do	do	Saw	1	6	20	.....
Do	do	do	Union	do	1	5	27	.....
Do	do	do	do	Flouring and grist	2	17	33	35
Do	do	do	Delaware	do	9	92	322	145
Do	do	do	do	Paper	2	22	165	120
Do	do	do	do	Saw	4	23½	81	.....
Do	do	do	Franklin	do	1	4	16	.....
Do	do	do	do	Flouring and grist	6	37	188	.....
Do	do	do	Madison	do	5	50+	169	.....
Do	do	do	Champaign	do	3	52	60	40
Do	do	do	do	Saw	3	59	75	.....

a Report by David S. Bates, principal engineer, in *Third Annual Report of Canal Commissioners*, January 8, 1825.

Table of utilized power on the Scioto river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall utilized.	Total water-power utilized	Auxiliary steam-power.
						Feet.	*H. P.*	*H. P.*
Tributaries	Scioto river	Ohio	Champaign	Woolen	2	12+	25	.....
Do	do	do	Fayette	Flouring and grist	3	25	54	35
Do	do	do	do	Saw	1	8	8	.....
Do	do	do	Pickaway	do	2	20	37	.....
Do	do	do	do	Flouring and grist	9	103	212	.....
Do	do	do	Fairfield	do	2	53	40	.....
Do	do	do	do	Saw	1	23	20	.....
Do	do	do	Hocking	do	2	13	16	.....
Do	do	do	do	Flouring and grist	4	41	86	.....
Do	do	do	Ross	do	9	81½	284	100
Do	do	do	do	Saw	3	23	66	.....
Do	do	do	do	Woolen	1	7	9	.....
Do	do	do	Vinton	Flouring and grist	1	.....	10	24
Do	do	do	do	Saw	1	4	8	.....
Do	do	do	Highland	do	2	20	40	.....
Do	do	do	do	Woolen	4	79	112	30
Do	do	do	do	Flouring and grist	11	114	288	137
Do	do	do	Adams	do	1	12	30	20
Do	do	do	Scioto	Saw	3	30	45	.....

THE GREAT MIAMI RIVER.

The main branch of the Great Miami river takes its rise in the central part of western Ohio, being formed by small streams heading in Logan and Hardin counties. Thence the general direction of flow is southwesterly to the Ohio river, which is joined in the extreme corner of the state, almost upon the boundary between it and Indiana. In a length which by general course is about 120 miles, this river traverses in turn the counties of Logan, Shelby, Miami, Montgomery, a corner of Warren, Butler, and Hamilton. Whitewater river, draining 1,482 square miles, is the largest tributary received, uniting with the main stream within a few miles of its mouth. In the middle course there enters from the west the Southwest branch, with a drainage basin of 710 square miles, and from the east Mad river, which drains 585 square miles.

The entire area naturally tributary to the Miami river comprises about 5,400 square miles, of which between 1,400 and 1,500 lie in Indiana. The southwestern portion of Ohio possesses a limestone soil, and is the most fertile part of the state. It is more thickly settled than any other section, contains numerous cities and large villages, is intersected in all directions by railroads, and is rich and prosperous. Attendant upon this prosperity, and contributing toward it in a large degree, has taken place an important growth in manufacturing-interests. These are much diversified, and are carried on both by steam- and by water-power; but in connection with the latter form of motive power is to be noticed especially the development of paper-manufacturing. The history of this industry in the Miami valley is included within the past thirty-five years. The processes at first employed in the manufacture were rude, and there were few mills; but the success of some of the early enterprises, and the natural advantages offered by this section of Ohio, have led to a large increase in the number of establishments, and the methods of manufacture have at the same time made great advances. According to the annual report of the secretary of state for 1879 there was produced in the fiscal year 1878–'79 at the mills of 27 firms or companies tributary to Cincinnati, located mainly along the Miami river and the Miami and Erie canal, paper as follows:

Kinds.	Pounds.	Value.
Book	11,497,694	$1,010,061
Manila	10,294,528	672,700
News	8,963,072	539,466
Roofing	5,356,219	144,194
Wrapping	10,438,455	244,347
Writing	1,817,000	249,000
Total	48,366,968	2,859,768

Some of the advantages enjoyed by this industry in the Miami valley consist of location in a section possessing much capital; fine conveniences for transportation, both by rail and by canal; and, not least, an abundant supply of pure wash-water, which is easily obtained from the gravelly subsoil, either by open or by driven wells. Straw is

plentifully and cheaply obtained, and some chemical straw-pulp is made in the valley. Poplar for wood-pulp can be found to a moderate extent in the northern part of the state, but the great bulk of the wood-pulp used is manufactured in, and shipped from, the northwest, especially Michigan.

Although its drainage basin is not large—the area tributary to that portion of the river mainly utilized ranging only from 1,900 to 3,300 square miles—nevertheless the stream has been improved to a considerable extent for power in the manufacture not only of paper, but also of flour, machinery, and various other goods. Its value for power arises from the advantages of location and communication which have already been noticed, and also from the possession of a more rapid fall in its main course, and a fuller and better-maintained volume of flow than characterize other streams of equal drainage area in this region. This character as regards flow is due to the abundance of permanent springs. In the report of surveys made fifty years or more ago, by the Hon. John Geddes, of the country between lake Erie and the Ohio river, it was stated that "the Great Miami has its source in a country the formation of which is very favorable to living springs". In the section drained by Mad river is extensively found a peat-like deposit which retains water like a sponge and gives to that stream a very uniform discharge. The northern and western portions of Ohio are covered by drift. In the southwestern part of the state, in the Miami valley, this is underlaid by the blue limestone formation, itself entirely impervious to water, but fringed along its border with fine springs.

Although in Logan county the surface of the country attains an elevation of over 1,500 feet above tide, the altitude of the dividing ridge between the Miami and Maumee rivers is in places much less, and, according to the original surveys for the Miami canal, is only 970 feet at the point where it was designed to carry across the summit-level. From Piqua to the mouth of the river, a distance of say 108 miles, the fall in water-surface is between 420 and 425 feet, an average of nearly 4 feet per mile, and that average rate of descent holds even in the lower 55 miles.

Table showing the fall in the Great Miami and Mad rivers.

Locality.	Distance from mouth.	Height of water-surface above mean sea-level.	Fall between points.	Distance between points.	Fall per mile between points.	Authority for elevations.
Great Miami river.	*Miles.*	*Feet.*	*Feet.*	*Miles.*	*Feet.*	
Maumee-and-Miami summit	.....	972	.....	.....	.....	Height of summit by original survey for Miami canal.
Piqua	108	849	124	31	4.00	Height of low water at crossing of the Pittsburgh, Cincinnati, and Saint Louis railroad, according to the profile of that road.
Dayton	77	725	69	22	3.14	Low-water surface of stream at crossing of the Cincinnati, Hamilton, and Dayton railroad is 285.45 feet above low water in the Ohio river at Cincinnati; the latter is assumed as 439.74 feet above sea-level, as determined by Mr. James T. Gardner.
Middletown	55	656	229	55	4.16	Obtained by adding to low water at Cincinnati the fall of the Miami and Erie canal, as given in canal report.
Mouth of river	0	427				Elevation of low water in the Ohio river, by survey of W. Milnor Roberts, 426.617 feet above ocean-level (see *House Ex. Doc. No.* 72, *Forty-first Congress, third session*).
Mad river.						
Four and a half miles west of Springfield.	21	888	163	21	7.76	Level of low-water surface at Indiana, Bloomington, and Western Railway crossing, according to surveys of that road.
Dayton, as above	0	725				

Scarcely any definite data concerning the amount of water flowing in the Miami river or its branches could be obtained. The Dayton Hydraulic Company relies upon Mad river for about 100 cubic feet per second in the driest part of an average year, an amount corresponding, for the 585 square miles of drainage area, to 0.17 cubic foot per second per square mile. July 3, 1867, during a tolerably low stage of water, Samuel Forrer, a prominent engineer of the state canals, gauged the Miami river at Dayton View, above Mad river, and found a discharge of 450 cubic feet per second. The drainage area above that point being 1,900 square miles, this discharge is equivalent to an average of 0.24 cubic foot per second per square mile.

The Miami and Erie canal, striking northerly from Cincinnati, reaches the immediate valley of the Miami river at Hamilton, then follows up the course of that river through its most important portion, and leaving it on the northern boundary of Miami county ascends the valley of Loramie's creek and passes over the summit-ridge into the Maumee basin. The first 66 miles of the canal above Cincinnati is supplied with water from the Miami and Mad rivers, the former being drawn upon near Middletown and Miamisburg, and the latter at Dayton. For the summit between the Miami and Maumee, and adjacent portions of the canal, reliance for a permanent supply is placed in a series of large reservoirs built and controlled by the state for that purpose. The principal of these are known, respectively, as the Saint Mary's or Mercer County, Loramie's, and Lewistown reservoirs. The Saint Mary's reservoir has elsewhere been alluded to as of remarkable size considering that it is entirely artificial, its surface covering an area stated by different authorities at 12,000 and 17,000 acres. As originally designed its flowage was 12,000 acres, its extreme length 10 miles, and its estimated storage when full over 4,000,000,000 cubic feet. It commands the drainage from about 200 square miles of territory.

From Piqua down to Dayton the course of the river is through the Devonian limestone, and the same cañon-like structure of valley is exhibited as along all the other streams running through that formation. Below Dayton

the valley is broad and open, flanked by low hills, between the bases of which the distance appears to be seldom less than a third or a half mile. The intervale is composed of level bottom-land, rich and largely cultivated for corn. The immediate banks vary considerably in height; at points they rise but a few feet above an ordinary stage of water, and again they range in height from 10 or 15 feet upward. While the river-bed is gravelly, the banks are of gravel and alluvial soil, the proportions of the two varying. The conditions are unfavorable to the building of dams of much height, unless at heavy outlay both for the structures themselves and for the flowage of land adjoining the river, or, if that is to be avoided, for its protection by dikes. On the other hand, the situation is well suited to long canals. At a moderate distance from the river the land becomes high enough to be above the reach of all ordinary freshets, and no rock-cuttings are necessary. In early days low rude dams were built here and there across the stream on shoals, and sufficient water was diverted into a little ditch to run, with the few feet of head obtained, some small grist- or saw-mills. As general manufacturing became introduced into this section, however, these privileges were purchased, one after another, the dams raised somewhat, and the canals extended so as not only to increase the head, but to convey the water to points where it could be utilized without danger of overflow from the river.

The principal places at which water-power is employed, from Dayton down stream, are, besides that city, Miamisburg, Franklin, Middletown, and Hamilton, at all of which water is conveyed through long canals ranging from 2 to 5 miles in length. The dams are of various construction—log, crib-work, framed work, and brush; the one at Franklin has a fall of 10 feet, claimed to be the highest on the river. At Franklin and Dayton View there is permanent power still open for lease, but at the other localities mentioned, although there is a surplus of water in some years, yet in others the supply falls short, and, so far as concerns reliable permanent power, those privileges are fully developed. Regarding a fair distribution of water to the various parties entitled to it, the conditions appeared much more satisfactory on this river than on most streams that were visited where there were many mills, the privileges here being as a rule controlled by joint-stock hydraulic companies, which attend to the proper maintenance of the works and division of the water. The latter is leased in so-called "runs" or "mill-stone powers", varying somewhat in size and price of rental at different localities, as shown below:

Rates charged by hydraulic companies for power at certain points in the Miami River valley.

Locality.	Company.	Equivalent of a run or mill-stone power.	Corresponding fall.	Theoretical power per run.	Established rental per run.	Rental per theoretical horse-power.	Remarks.
		Cubic feet per minute.	*Feet.*	*H. P.*			
Dayton	Cooper Hydraulic Company	315	12	7.16	$200±	$27 93	On Miami and Erie canal; rates vary between $150 and $300.
Do	Cooper Hydraulic Company (lower privilege)	400	8	6.06	150±	24 75	
Do	Dayton Hydraulic Company	233+	15	6.62	200	30 21	On Mad river.
Dayton View	Dayton View Hydraulic Company	300	12	6.81	250	36 71	On Miami river.
Franklin	Franklin Hydraulic Company	300	12	6.81	200	29 37	Do.
Middletown	Middletown Hydraulic Company	203+	18	6.91	200	28 94	Do.
Hamilton	Hamilton & Rossville Hydraulic Company	300	12	6.81	130–300	19 09–44 05	Do.
West Hamilton	West Hamilton Hydraulic Company	375	(?)	.....	200	.....	Do.

Of the 300 feet of fall in the Great Miami below Dayton to the junction with the Ohio river, there has been improved for water-power at Miamisburg about 21 feet, at Franklin 16½ feet, at Middletown from 15 to 18 feet, and at Hamilton 24 feet—a total of say 75 or 80 feet. Between Hamilton and the mouth the river is reported to be utilized for power by several small saw- and grist-mills, but through most of this distance it is without railroad facilities and was not visited. Probably the entire developed fall below Dayton does not exceed 90 or 100 feet. How much more might successfully be improved can be determined only by a detailed examination and survey, since the descent is not concentrated in falls and heavy rapids, but is distributed with comparative uniformity. Toward the Ohio the liability to trouble from the backwater of that river is of course to be considered. The Miami itself, like all the other streams of this section, is visited by heavy freshets, which rise above the low places in its banks, and at times even reach high ground, but no difficulty is experienced in finding safe locations for mills, and the trouble from backwater is not looked upon as serious. At Franklin an extreme freshet-rise does not reach a height of more than 12 or 14 feet above low water. Anchor-ice runs in the river more or less in winter, and at Hamilton it was stated that the surface is sometimes seen covered with it.

Power at Hamilton.—Hamilton is a city of 12,000 inhabitants, distant 25 miles from Cincinnati on the Cincinnati, Hamilton, and Dayton railroad, and is the first important site, ascending the river, where water power is used. It is finely situated on level ground, well suited to carrying the canals and to the convenient location of mills. The river is here 300 or 350 feet wide between banks, and is utilized both on the east side in the city of Hamilton, and on the west bank at West Hamilton. The privilege on the east side is owned by the Hamilton and Rossville Hydraulic Company, and has been in continuous use for some thirty-five years. A low dam, not more than 3 or 4 feet high, and rudely built of brush and stone, diverts water into a canal in which it is brought down about 5 miles to the city. There the main canal extends some distance in a north-and-south direction, while a branch runs across

to the river-bank and follows that. Water is drawn from this level under three different falls: First, by mills discharging directly into the river and utilizing the full fall of 24 feet; second, a considerable portion is employed under a fall of 12 feet by mills discharging into a tail-race which runs parallel to the main canal, but in the opposite direction, extending up to an old channel of the river and there emptying; third, a part is also used under a fall of 7½ feet, and is then passed into a second level, the canal running over to the river, to which the water finally descends after being employed by mills under a fall of about 16 feet. Since quite an amount of water is returned to the river before having been utilized for the full available fall, it is evident that the entire power of the privilege is not realized.

The water-power at Hamilton is extensive, and is chiefly used by the following works: 4 large paper-mills, 3 or 4 machine-shops (one of them employing 300 hands), 3 flouring-mills, 1 woolen-mill, 2 manufactories of agricultural implements, 1 of saws, and others of plows, bran-dusters, chicken-coops, hubs, spokes, fellies, and various other articles in wood. Paper-making, machine-work, and flouring may be regarded as the principal industries.

Water is leased by the hydraulic company in mill-stone powers, a single one of which is defined as 300 cubic feet per minute with a fall of 12 feet. Its actual division is effected by delivering it over fixed iron weirs, so arranged that with a full canal each weir shall pass the amount to which the lessee is entitled. In January, 1883, there were in use 33 runs, or mill-stone powers, under 24 feet of fall, 14 under 16 feet, 42 under 12 feet, and 7 under 7½ feet. Most of the mills also have steam-power for use in low water. This is rendered necessary in some years, during the summer or fall, for periods ranging as high as six weeks and even two or three months. Some of the early leases on this privilege were made at $130 per annum per run, but the rental has been increased in more recent leases, and runs as high as $300. There are a few runs of nine months' water—liable to be shut off during three months of the year—but the rest stand all upon equal footing as respects rights to water during low stages of river. A deduction in rental is made for the time during which there is a shortage of water.

Backwater causes some trouble here during high freshets, and more or less hinderance is also experienced nearly every year owing to the temporary character of the dam. It rests upon a gravel bed, and being of the rude construction already alluded to is easily injured by ice or violent freshets, thus endangering the supply in the hydraulic canal. The latter varies in width, spreading out in places where the ground is favorable, and forming one large reservoir of about 100 acres and a second smaller one. For a mile from the dam, down to the large reservoir, the canal is quite uniform in size, designed, where in excavation, to be 30 feet wide at the bottom, with side-slopes of 1¾ to 1. In its extreme upper course it follows the river-bank, and is there exposed to washing of its own banks and even to submergence during unusual freshets.

On the west side of the river the privilege in use is owned by the West Hamilton Hydraulic Company. The dam is a log structure, located something over a mile up stream, and of course below the dam already described. The race supplies water to two flouring-mills, one saw-mill, and one furniture factory. The fall from the water-surface in the race to low water in the river is given as 16 feet, but a little of this is lost in a tail-race which runs by the mills and receives the water discharged from each. All these mills use overshot wheels, the largest stated to be 10 feet in diameter. Water is leased in runs, a run being defined as 375 cubic feet per minute, and presumably embracing the full available fall of the privilege; the rental charged is $200 per annum. This power has to depend for its supply of water upon what passes the upper dam and upon the discharge of Seven-Mile creek, which enters the Miami river between the two dams, and for about two months in the year there is a scarcity.

Power at Middletown.—Some 2 or 3 miles above the village is a state dam for diverting water to the Miami and Erie canal. In January, 1882, there was a heavy freshet in the Miami river, and the river-bed, which is composed of gravel at the site of the dam, was thought to have been washed away from beneath the structure so as to permit a settling which took place about 50 feet from the south abutment. The abutment itself next settled, and in February a breach occurred in the dam through which the entire volume of the river poured. The gap was closed by temporary brush-work, which, together with about one-third the old dam, was standing at the time this place was visited in the succeeding winter. It was designed, however, soon to replace the old structure by a framed dam.

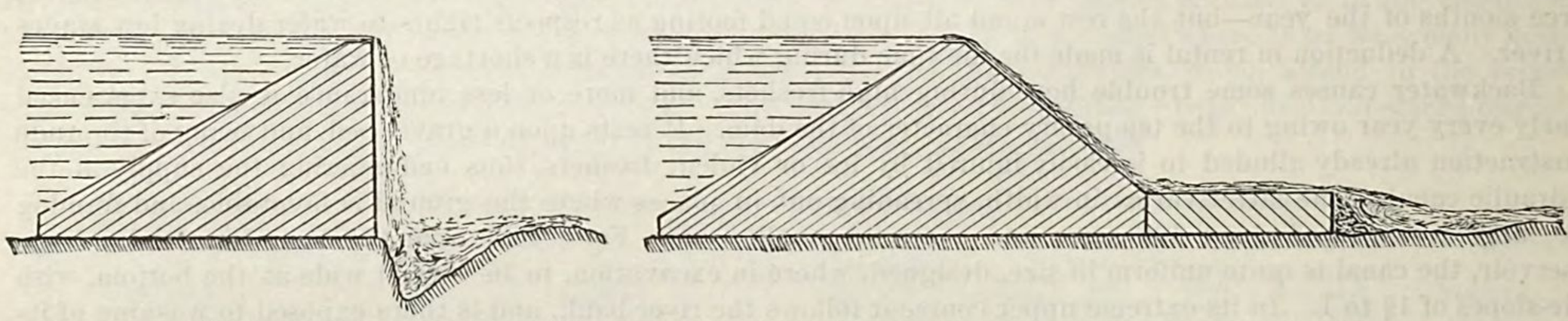
Of the water diverted by this dam a certain number of cubic feet is reserved by the state for feeding the Miami and Erie canal, while the balance, so far as needed, is conveyed through a hydraulic race, 2¾ miles long, to the village of Middletown, a place of 4,500 inhabitants, lying on the east bank of the stream. It is there utilized for power by five paper-mills, one flouring-mill, one machine-shop and pump-factory, and one planing-mill. Manila is the principal variety of paper manufactured, and the combined capacity of the mills is stated to be not less than 35 or 40 tons of paper per day.

The water-privilege is owned by the Middletown Hydraulic Company. Water is leased in mill-stone powers, the regular rental, from which there are few variations, being $200 per annum. The fall at the mills ranges from 15 to 18 feet, and the volume of water per mill-stone power varies correspondingly, but for a fall of 18 feet is defined as 203.22 cubic feet per minute. Water is measured out to the mills over fixed weirs. The hydraulic company reserves the right to a stoppage of supply for thirty days in the year, if necessary, and the volume flowing in the race is further liable to be more or less curtailed in summer or autumn by low water in the river, but allowance for such shortage is made in rental at the end of the year. It is said that the leases prescribe the use of overshot wheels, but in fact the majority, if not all, in use are turbines. If, by reason of a low stage of river, the supply of water becomes insufficient for the mills, these are shut off in order according to date of lease, the most recent first.

Up to January, 1883, about 95 mill-stone powers of water had been leased at Middletown, covering practically all the permanent power. In some years there is abundance of water throughout, but in others some scarcity, though even in extremely dry years the mills are fully supplied for nine months, and the hydraulic company is prepared still to lease power which may be relied upon for eight or nine months in the year.

Power at Franklin.—The dam at this point is about 600 feet long, with a fall from the crest of 10 feet in low water, and the hydraulic company has the right to raise it 3 feet. The actual height of the structure from foundation is much more than just stated, even reaching 30 feet in places where there has been scour and it has been necessary to fill in. The river-bed for not exceeding one-third its width at the site of the dam is rock, and the rest of the way sand and gravel. The original structure was called a "pole" dam and was built very much like a log dam, except of smaller timber not more than 5 or 6 inches thick at the butts. The breast did not, however, project far enough beyond the crest, the overpouring water produced heavy scour, and the dam was carried out. The volume of water flowing over in a heavy freshet is very great, and leaves but little difference of level above and below the dam.

The present structure has been built up as necessity required the renewal of old work—in 1874, '75, '76, and '81. In general terms, one-third is a log dam of the usual style, one-third a log and stone crib-work, and one-third of the old pole pattern. For the first, logs perhaps 50 feet long were employed, the requisite back slope being gained by cross-logs or binders placed in the breast, which was carried up as a series of offsets to serve as an apron. The spaces between the logs were filled in with stone. The crib-work portion of the dam has a tolerably long and regular slope each way from the crest. At the foot of the front slope is a crib-work apron 4 feet high, its farther extremity about 40 feet from the crest of the dam. Great importance is attached to this apron as preventing scour. When the

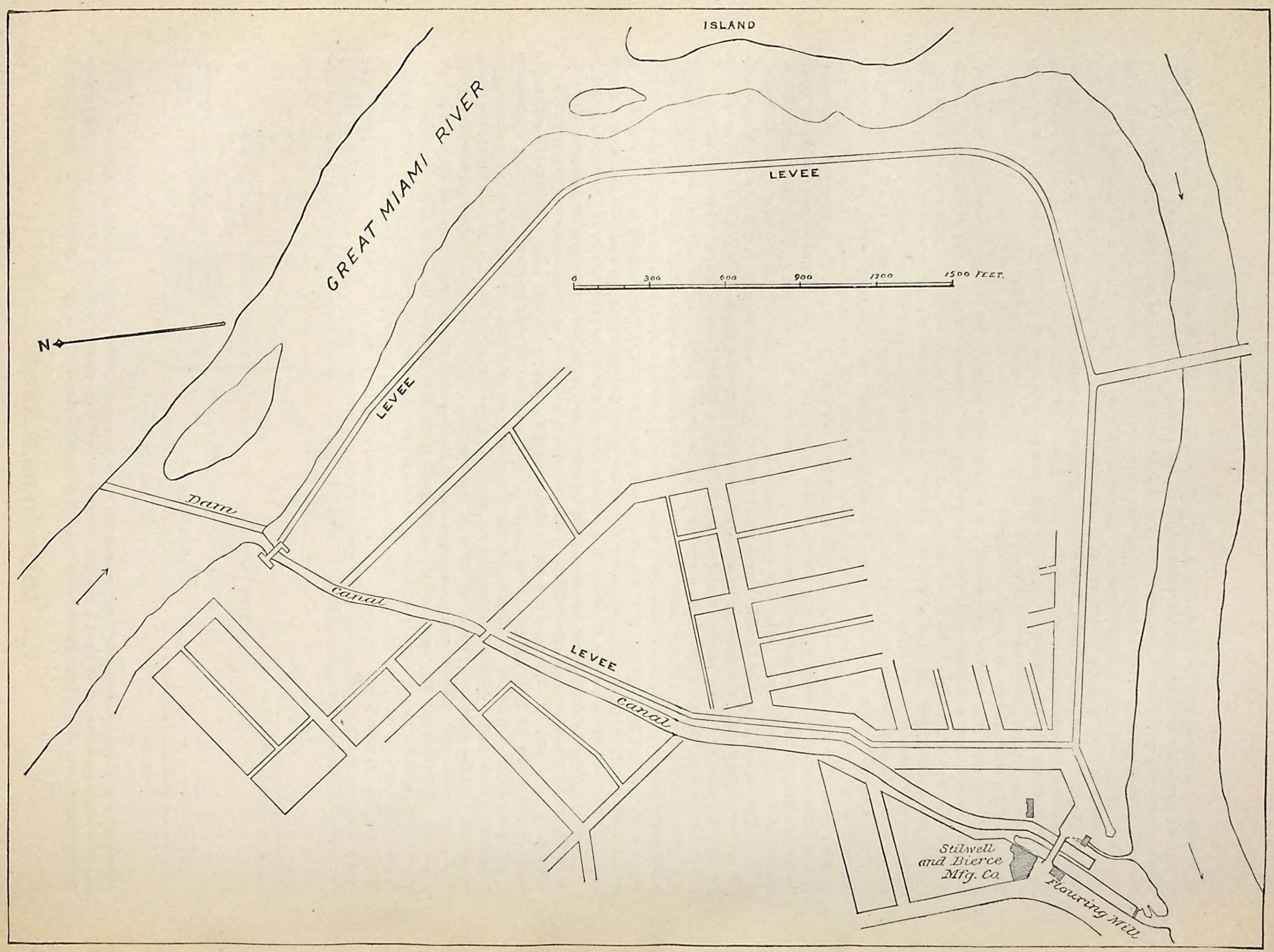


SKETCH SHOWING ACTION OF WATER IN PRODUCING SCOUR, AND CONSTRUCTION FOR AVOIDING IT.

breast of a dam has a steep slope (and in many cases it is built vertical), unless the river-bed below is of rock or receives artificial protection, it is certain to be worn out by the overfalling water and the safety of the dam to be threatened. If, however, the slope be reduced and supplemented by an apron, especially if the latter be given a slight upward pitch, the falling water is deflected forward and possibly even a little upward after leaving the apron, and thus appears to establish a return undercurrent, setting toward the end of the apron and tending to build up a deposit instead of scouring out the bed. It was stated by Mr. A. E. Harding, president of the hydraulic company, that by the action mentioned material has been filled in 20 feet deep at the foot of this dam, where during the life of the old structure a deep hole had been formed, and that in places it has even accumulated above the level of the top of the apron. There is no sheet-piling either above or below the Franklin dam. Neither here nor elsewhere on the Miami river does the pondage obtained appear to be of special importance, because of the general use of power by paper-mills which run night and day.

From the dam a hydraulic race is carried some 2 miles down the east side of the river to Franklin, its depth estimated at 6 or 7 feet, and its minimum width at 50 feet on the water-surface, while at many points it widens out considerably. The fall from the water-surface of the race at its foot to low water in the river is about 16½ feet. Power is in use by one writing- and one manila-paper mill, also by one planing- and one grist-mill. The Harding Paper Company manufactures fine writing-papers, and is said to be, with a single exception, the only concern engaged in that business in the West. The company occupies a handsome brick mill, and in January, 1883, had a capacity for producing 3 tons of paper per day; the works were also at that time being enlarged to a capacity of 6 tons per day. The company has another mill for the manufacture of fine writing-paper at Excello, on the Miami and Erie canal, where a fall of 10 feet is obtained around a lock.

The privilege which has been described is nominally owned by the Franklin Hydraulic Company, a joint-stock concern. The whole property is leased, however, for a period of twenty-eight years to the Harding Paper Company, which also controls a majority of the stock. A "run" or "mill-power" at Franklin is 300 cubic feet of water per minute under a fall of 12 feet, for which the established rental is $200 per annum. In January, 1883, seventy-eight runs were controlled under lease by the various mills and more or less completely utilized in manufacturing, and negotiations had nearly been completed for disposing of six more runs. The mills now in operation have abundance of water, and no measurements are made or weirs used. It is considered by the hydraulic company that in the average of years the privilege can be relied upon to furnish one hundred runs continuously, and a total of at least two hundred runs for ten months. The village of Franklin is attractively located, and had, in 1880, a population of 2,400. While no special inducements are held out, aside from the natural advantages of the place, other



Plan of Water Privilege at Dayton View, Great Miami River.

manufacturing enterprises can obtain power here, and there is abundance of fine building-room. The Harding company owns twenty acres adjoining the lower course of the race, and this, together with five or ten acres more adjoining, is available for mill-sites. The theoretical power of this privilege may be estimated as follows:

Estimate of power at Franklin.

Stage of river.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		Effective horse-power of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.					
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	1 *foot fall.*	16 *feet fall.*	
Low water, dry year	10½	12	8½	9	40	2,710	330	37.5	600	280±
Low water, average year							430	48.8	780	
Available 10 months, average year							620	70.4	1,130	

Power at Miamisburg.—Miamisburg is a village of 1,900 inhabitants, 10 or 12 miles below Dayton, on the Cincinnati, Hamilton, and Dayton railroad. The Miami river is here from 250 to 350 feet wide between banks, and 2½ miles above the village is controlled by a dam—a framed structure 4½ feet high, resting on a gravel bed. The present dam was built about the year 1873, but the privilege was in use probably seventy-five years ago. From the dam, a hydraulic race, 40 feet wide at water-surface, runs about a mile and a half and then enters the Miami and Erie canal. By a contract with the state the Miamisburg Hydraulic Company, proprietor of the privilege, uses 1 mile of the state canal, and in return maintains repairs on that mile and furnishes water so far as needed for navigation. At the village of Miamisburg water for power is drawn by the mills directly from the state canal and discharged into the river. The extreme fall from the Miami and Erie canal to low water in the river is stated as about 21 feet, but the falls in actual use range from that figure down to 17 feet and even less. Power is utilized by the Ohio Paper Company and the Miami Valley Paper Company, manufacturers of book and news paper, with a combined capacity of 6 tons per day; also by a sash-and-blind shop and a flax-breaking mill. The permanent power of the privilege has all been leased, and the company is not prepared to dispose of any more rights to water at present.

Power at Dayton View.—Dayton View is on the right bank of the Miami, opposite the city of Dayton. The river here makes a bend about 2 miles in length, and across the neck a race has been carried to the mills, which are on the lower side of the bend. Stillwater creek enters the Miami not far above the dam, and Mad river empties between the dam and the tail-race. For fifty years there has been a dam on this privilege, at first a rude affair of brush and stone, but within a dozen years the hydraulic company has come into possession and done a large amount of work on the structure. At various times previously great quantites of bowlders, locally known as "nigger-heads", had been hauled on, and the company has itself added 3,000 perches. These bowlders weigh in many cases several hundred and even a thousand pounds each, and are obtained from the hilly ground adjoining the valley.

As reconstructed, the dam has a length of 650 feet and a fall from crest to low water in the river below of about 6½ feet. The natural bed of the stream is floored, so to speak, with the remains of the old dam for a distance with the current of perhaps 80 feet. Upon this foundation rests the dam proper, built of log cribs 12 feet square, all interstices carefully packed with bowlders and gravel. The main crib-work extends with the stream the length of two of these squares, or say 25 feet, and has an abrupt back slope, while the top has a long inclination down stream. Behind each series of transverse logs sheet-piling has been driven into the river-bed in double rows, breaking joints. This piling has a slant up stream, and against it is a mass of bowlders closely packed. The sheet-piling and logs, the plank covering of the dam and the logs, and the different courses of the logs themselves, are all firmly secured together by drift-spikes. Above the main structure is a heavy backing of loose stone. Below the dam transverse logs, planked over and having the spaces filled in with stone, form an apron projecting 16 feet down stream. The dam was at first left without any plank covering, but it was found that the action of ice-freshets was to force out the stone filling and threaten the security of the structure. Afterward the upper crib-work was covered with 3-inch planking, and then, successively, the lower crib-work and apron were covered, it being observed that in each case the bowlders were carried out from the portion left unprotected. The dam is now considered safe, durable, and tight.

A masonry bulkhead with head-gates has been built by the hydraulic company, at a cost of from $6,000 to $8,000, and admits water to the canal, which is about three-quarters of a mile long, designed with a width of 50 feet at water-surface and a water-depth of about 6 feet. Where this race reaches the vicinity of the river again are located the mills, power being utilized by the Stillwell & Bierce Manufacturing Company, manufacturer of turbine water-wheels; by A. A. Symonds, manufacturer of cutting-bar knives for paper-mills, planing and machine knives; and by C. B. Palmer & Co. for a flouring-mill. Between the dam and tail-race the river descends 4 or 5 feet, making the fall at the mills nearly or quite 11 feet, and by raising the dam 1 foot the hydraulic company claims that an available fall of 12 feet will be realized. This is, of course, subject to important reduction during high water, and in extreme freshets may be obliterated entirely; still, serious trouble from this source is not of long duration, the mills themselves are out of reach of high water, and the head-race and adjoining meadows are well protected by dikes.

The water-privilege is owned by the Dayton View Hydraulic Company, capital stock $75,000, which leases land and water to manufacturers for terms of ninety-nine years. A "run" is here defined as 300 cubic feet of water per minute under a fall of 12 feet, for which the regular rental is $250 per annum. The company is proprietor of 16 acres of land adjoining the lower part of the race, suitable for building-sites, and is desirous of leasing this, together with the remainder of its power. It assumes that with a fall of 12 feet it has forty-three permanent runs, and of these eleven had been leased by January, 1883. The site is without direct railroad facilities, but the haul for freights across the river to and from depots in the city of Dayton is not a long one, and there are convenient bridges.

Estimate of power at Dayton View.

Stage of river.	Rainfall on basin.					Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		Effective horse-power of wheels in use.
	Spring.	Summer.	Autumn.	Winter.	Year.					
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. miles.*	*Cubic feet.*	*1 foot fall.*	*12 feet fall.*	
Low water, dry year	10½	12	8½	9	40	1,900	200	22.7	270	150±
Low water, average year							270	30.7	370	
Available 10 months, average year							420	47.7	570	

The examination of the main river did not extend above Dayton. According to the census enumerators' returns the use of power above that point is confined chiefly to small flouring- and saw-mills, with an occasional paper- or oil-mill, and may sufficiently well be learned from the table of utilized power.

Drainage areas of the Great Miami river and tributaries.

Stream and locality.	Drainage area.	Stream and locality.	Drainage area.
	Sq. miles.		*Sq. miles.*
Great Miami river at Piqua	890	Southwest branch at mouth	710
Great Miami river at Troy	950	Mad river near Springfield, above Lagonda creek	271
Great Miami river at Dayton, above Mad river	1,900	Lagonda creek at mouth	180
Great Miami river at Dayton, below Mad river	2,485	Mad river below junction with Lagonda creek	451
Great Miami river at Miamisburg	2,640	Mad river at mouth	585
Great Miami river at Franklin dam, 2 miles above village	2,710	Elk creek at mouth	347
Great Miami river at Middletown dam, 3 miles above village	3,080	Seven-Mile creek at mouth	307
Great Miami river at Hamilton dam, 5 miles above city and assumed to be above Seven-Mile creek	3,320	Whitewater river at Connersville	456
		Whitewater river at Brookville	1,217
Great Miami river at mouth	5,400	Whitewater river at mouth	1,482

Mad river, one of the most important tributaries of the Miami, which it joins at Dayton, has its source some 50 miles to the northeast of that city, in Logan county. Its drainage basin comprises 585 square miles. As has elsewhere been noticed, the river is characterized by a well-sustained flow, which is due to a great abundance of springs in the surrounding country and to the presence of extensive swampy tracts of land. It has in general a gravelly bed, and along its course are met the usual drift materials—gravel, clay, bowlders, and sand. At Snider's mill, near Springfield, rock appears, while at a bridge site not far below, a deposit of sand 40 feet deep is said to have been encountered. Other large deposits of sand occur in the vicinity, and it is the water leaching out from these which seems to have produced some of the "cat-head" swamps. From Dayton up nearly to Springfield the stream is bordered by low and wide flats or bottoms, beyond which, at a moderate elevation, is the rolling upland country. Not far west of Springfield, however, the valley narrows for a time and is flanked by rocky walls. The descent of the stream is tolerably rapid, amounting in about 21 miles above the mouth to 163 feet, an average of nearly 8 feet per mile. Many good water-privileges exist and are but partially utilized. Formerly there were numerous distilleries along Mad river, but within the past twenty years the industry they represented has greatly declined in this valley.

The largest use of power is at Dayton, a fine city of 37,000 inhabitants and an important manufacturing point. Water is drawn from Mad river some distance above the city, and above the dam by which the state diverts water for feeding the Miami and Erie canal. Some power has been in use on the privilege from the early part of the century, but the principal manufacturing at Dayton has developed since 1835, and the Dayton Hydraulic Company's works were constructed about ten years later. The dam has grown by accretions. It was originally built as a rough affair of timber, brush, and stone, rudely thrown up, but from time to time additions have been made of large bowlders, carefully packed, and in such manner as to give a somewhat regular shape to the dam, with a sloping face and apron. The interstices have been filled with gravel, and the sediment of the river has settled in and made the structure tight, so that in low water there is no leakage through it, though seepage takes place under it through the gravelly bed on which it rests. Although the dam is a substantial one, nevertheless after the severe winter of 1880–'81 a heavy run of ice carried away a part, making a breach perhaps 40 feet long. This portion was solidly

rebuilt, however, with timber, limbs of trees, brush, and bowlders, and is now considered to be as strong as any other part of the structure. In low water the fall from the crest to the river-surface below is about 7 feet.

The race extends about 2½ miles down to the city, and, with one exception, the mills are located at its extremity. This race is irregular in width, but is estimated to have ample capacity, when not obstructed by ice, for passing 10,000 cubic feet of water per minute; when frozen over its capacity is diminished at times to 8,000 cubic feet, and to even less in exceptional cases. Water is supplied for power to three flouring-mills, two paper-mills, two flax-mills, two plow manufactories, and one linseed-oil mill. The tail-water from these mills is discharged into the Miami and Erie canal. The hydraulic company has a contract with the state, by virtue of which it is entitled to discharge into the canal 10,000 cubic feet of water per minute, and as much more as necessary, provided no injury be done to the canal. The "head and fall" is reckoned at 15 feet, but is subject to slight variations from changes of level in head- and tail-race. The leases permit the use of overshot wheels of 13½ feet diameter, and that class of wheels is employed in all cases, except by the Meade Paper Company, the largest single user of power, this company having turbines. Water is drawn from the race through rectangular apertures between square-edged metallic plates, which are adjustable. The aperture is as close as convenient to the wheel, the width of opening being governed by the width of the wheel, for overshots, and the depth by the quantity of water to be supplied. As the level in the races varies, the aperture is correspondingly adjusted, and the power is maintained comparatively uniform.

A run of water is here fixed at 233⅓ cubic feet per minute, under a head and fall of 15 feet. There are assumed to be 26¼ permanent runs, and for the average of a series of years the assumption is stated to prove quite accurate. In January, 1883, all these runs had been leased, and, in addition, 24 temporary runs, liable to be shut off in low water. The rate charged for permanent power is $200 per annum per run, and the same in proportion for temporary power. Throughout the year 1882 there was sufficient water for all the runs, both permanent and temporary, and a waste on the dam besides; while in 1881, for a time, not even all the permanent runs could be supplied. Both land and water are leased to the manufacturers by the hydraulic company.

Ascending above Dayton, power is utilized at short intervals along the course of the river, mainly by flouring-mills, of which there are 8 within perhaps 20 miles. These range in capacity from 150 barrels per day downward, and in connection with some of them are operated other small works such as corn-mills, saw-mills, and distilleries. A fall of 10 feet was reported to be in use by a paper-mill at Enon, and a few miles above Dayton a privilege with 14 feet of fall, owned by John Harries and formerly utilized by a flouring-mill, was found idle. These were the only powers on the section of river visited possessing as great a fall as 10 feet, the range at other points being only from 5 to 8 feet. Near Springfield the river is joined by Lagonda creek, which flows through that city and is taken advantage of for power by several manufacturing concerns, among them the firm of P. P. Mast & Co., extensive manufacturers of agricultural implements.

Above Lagonda creek the volume of Mad river is, of course, considerably smaller than toward the mouth, the tributary drainage area being less than one-half as great as at Dayton, but the stream continues to be employed for power at frequent intervals all the way to its headwaters, mainly by flouring-mills.

Table of utilized power on the Great Miami river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Great Miami river	Ohio river	Ohio	Hamilton	Flouring and grist	2	6	56	.....	Cleves and Whitewater.
Do	do	do	do	Saw	2		38	.....	
Do	do	do	do	do	1	4½	10	.....	Cleves.
Do	do	do	do	Flouring and grist	1		20	.....	
Do	do	do	do	do	1	5	30	.....	Crosby.
Do	do	do	Butler	Flouring, grist, and saw	1	4	45	.....	Ross.
Do	do	do	do	Agricultural implements	2	Total fall on privilege, about 24 feet.	15+	80	Hamilton and West Hamilton.
Do	do	do	do	Bread, crackers, etc	1		40	.....	
Do	do	do	do	Blacksmithing	1		16	.....	
Do	do	do	do	Carriage and wagon materials.	2		25	55	
Do	do	do	do	Flouring and grist	5		160	.....	
Do	do	do	do	Furniture	1		12	.....	
Do	do	do	do	Hardware	1		45	.....	
Do	do	do	do	Machinery	3		60	.....	
Do	do	do	do	Marble- and stone-works	1		30	.....	
Do	do	do	do	Paper	4		298	250	
Do	do	do	do	Sashes, doors, and blinds	4		52	42	
Do	do	do	do	Saw	1		16	.....	
Do	do	do	do	Wheelwrighting	1		16	.....	
Do	do	do	do	Woolen	1		40	40	

Table of utilized power on the Great Miami river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Great Miami river	Ohio river	Ohio	Butler	Flouring and grist	1	15 to 18	96		Middletown.
Do	do	do	do	Lumber, planed	1				
Do	do	do	do	Machinery	2		16+		
Do	do	do	do	Paper	5		705+	690	
Do	do	do	do	Sundry articles in wood	(?)				
Do	do	do	Warren	Flouring and grist	1	16	22		Franklin.
Do	do	do	do	Lumber, planed	1		9		
Do	do	do	do	Paper	2		250±		
Do	do	do	Montgomery	Flax-beating	1	17–21			Miamisburg.
Do	do	do	do	Paper	2		110+	35	
Do	do	do	do	Sashes, doors, and blinds	1		12		
Do	do	do	do	Cutlery and edge-tools	1	10–11	150±		Dayton View.
Do	do	do	do	Flouring and grist	1				
Do	do	do	do	Turbines	1				
Do	do	do	Miami	Linseed oil	1	18–22	40		
Do	do	do	do	Paper	1		50		
Do	do	do	Shelby	Flouring and grist	2	20	76		
Do	do	do	do	Iron castings and finishings	1		16		
Do	do	do	Logan	Flouring and grist	3	10+	60		Miami and Pleasant townships.
Do	do	do	do	Saw	2		25		
Mad river	Great Miami river	do	Montgomery	Agricultural implements	2	13–15	500±	650	"Dayton" hydraulic canal.
Do	do	do	do	Flax, dressed	2				
Do	do	do	do	Flouring and grist	3				
Do	do	do	do	Linseed oil	1				
Do	do	do	do	Paper	2				
Do	do	do	do	Flouring and grist, etc	2	14	86		
Do	do	do	Greene	Flouring, grist, and saw	1	6	20		
Do	do	do	Clark	Paper	1	10			
Do	do	do	do	Flouring and grist	4	22	157		
Do	do	do	Champaign	do	2	18	55		
Do	do	do	do	Flouring, grist, and saw	2	19	100		
Do	do	do	Logan	Flouring and grist	3	54	108	60	
Tributaries	Mad river	do	Greene	do	1		20		
Do	do	do	Clark	do	8	150	273		
Do	do	do	do	Saw	2	33	32		
Do	do	do	do	Paper	1	9½	195	180	Possibly identical with a mill given on the main stream.
Do	do	do	do	Agricultural implements	1	24	100	85	
Do	do	do	do	Vegetable oil	1	40	30		
Do	do	do	Champaign	Flouring and grist	4	64	95	61	
Do	do	do	do	Woolen	1	18	12	30	
Do	do	do	Logan	Flouring and grist	1	21	80		
Whitewater river	Great Miami river	do	Hamilton	do	1	7	45		
Do	do	Indiana	Dearborn	do	4	24	170	100	
Do	do	do	Franklin	do	1	16	25		
Do	do	do	do	Machinery	1	12	3		
Do	do	do	do	Paper	1	15	150	100	
Do	do	do	do	Saw	1	8	38		
Do	do	do	Fayette	Coffins	1	17	20	16	
Do	do	do	do	Flouring and grist	3	46	95		
Do	do	do	do	Furniture	1	25	35	45	
Do	do	do	do	Machinery	1	26	15		
Do	do	do	do	Saw	1	8	15		
Do	do	do	Wayne	Cider	1	14	10		
Do	do	do	do	Flax, dressed	1	9	17		
Do	do	do	do	Flouring and grist	8	124½	301	100	
Do	do	do	do	Linseed oil	1	14	22	22	
Do	do	do	do	Paper	1	8	39	55	
Do	do	do	do	Pianos	1	12	40		
Do	do	do	do	Saw	1	11	40		
Tributaries	Whitewater river	do	do	do	6	54½	93		
Do	do	do	do	Machinery	1	17	45		
Do	do	do	do	Woolen	3	45	45	5	
Do	do	do	do	Flouring and grist	17	286+	575	20	
Do	do	do	Union	do	5	49	85	24	
Do	do	do	do	Saw	1	18	25		
Do	do	do	Franklin	Flouring and grist	7	74+	206		

Table of utilized power on the Great Miami river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Tributaries	Whitewater river	Indiana	Fayette	Pumps	1	7	5	.....	
Do	....do	....do	....do	Saw	1	19	10	.....	
Do	....do	Ohio	Preble	....do	1	13	16	.....	
Do	....do	....do	....do	Flouring and grist	2	20	35	.....	
Sundry small streams	Great Miami river	....do	Butler	....do	9	95+	352	.....	
Do	....do	....do	....do	Saw	4	41	90	.....	
Do	....do	....do	Warren	Woolen	1	2	12	.....	
Do	....do	....do	....do	Flouring and grist	6	107	112	.....	
Do	....do	....do	Montgomery	....do	13	200½	373	.....	
Do	....do	....do	....do	Saw	7	115	102	12	
Do	....do	....do	Preble	....do	4	31+	92	.....	
Do	....do	....do	....do	Woolen	2	67	22	.....	
Do	....do	....do	....do	Flouring and grist	11	139	262	175	
Do	....do	....do	Darke	....do	5	58	104	.....	
Do	....do	....do	....do	Saw	1	5	10	.....	
Do	....do	....do	....do	Woolen	1	12	18	.....	
Do	....do	....do	Miami	Flouring and grist	14	198	533	25	
Do	....do	....do	....do	Saw	5	59	103	.....	
Do	....do	....do	....do	Woolen	6	105+	72	.....	
Do	....do	....do	Clark	Saw	3	28+	92	.....	
Do	....do	....do	Champaign	Flouring and grist	1	25	12	.....	
Do	....do	....do	Logan	....do	8	144	180	12	
Do	....do	....do	....do	Saw	2	23	50	.....	
Do	....do	....do	Shelby	Flouring and grist	3	50½	76	.....	

Table of utilized power on various minor tributaries of the Ohio river (above the mouth of the Miami river on the north, and above the mouth of the Little Kanawha river on the south).

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.
						Feet.	*H. P.*	*H. P.*
Little Beaver river and tributaries	Ohio river	Ohio	Columbiana	Flouring and grist	14	187	377	60
Do	....do	....do	....do	Saw	2	12+	31	.....
Do	....do	....do	....do	Woolen	1	19	6	6
Hocking river and tributaries	....do	....do	Athens	....do	1	7	20	.....
Do	....do	....do	....do	Flouring and grist	6	41	258	.....
Do	....do	....do	Hocking	....do	3	21	60	.....
Do	....do	....do	... do	Saw	1	8	20	.....
Do	....do	....do	Perry	Wheelwrighting	1	14	4	.....
Do	....do	....do	Fairfield	Flouring and grist	6	84	89	.....
Little Miami river and tributaries	....do	....do	Hamilton	... do	3	16	124	.....
Do	....do	....do	Clermont	....do	6	71	154	.....
Do	....do	....do	Warren	....do	10	81½	399	.....
Do	....do	....do	....do	Gunpowder	1	5	100	.....
Do	....do	....do	....do	Saw	6	46½	200	.....
Do	....do	....do	Greene	Flouring and grist	15	192½	477	76
Do	... do	....do	....do	Gunpowder	1	9	120	200
Do	....do	....do	....do	Paper	1	26	55	50
Do	....do	....do	....do	Saw	9	53	210	16
Do	....do	....do	Brown	Flouring and grist	1	7	8	36
Do	....do	....do	Highland	....do	1	7	16	8
Do	....do	....do	Clinton	....do	4	44	73	50
Do	....do	....do	....do	Furniture	1	10	20	.....
Sundry small streams	....do	....do	Clermont	Flouring and grist	1	20	20	25
Do	....do	....do	Brown	....do	11	158+	251	150
Do	....do	....do	Adams	Flouring and grist	8	143	139	138
Do	....do	....do	....do	Saw	2	27	30	40
Do	....do	....do	Scioto	....do	3	24	64	.....
Do	....do	....do	....do	Flouring and grist	3	24	147	.....
Do	....do	....do	Lawrence	....do	6	46	146	.....

Table of utilized power on various minor tributaries of the Ohio river, etc.—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.
						Feet.	*H. P.*	*H. P.*
Sundry small streams	Ohio river	Ohio	Lawrence	Saw	1	7	8	.....
Do	do	do	Gallia	do	3	19	90	.....
Do	do	do	do	Woolen	2	18	33	.....
Do	do	do	do	Flouring and grist	10	63	211	.....
Do	do	do	Jackson	Flouring, grist, and saw	1	8	32	.....
Do	do	do	Vinton	Saw	5	44	75	.....
Do	do	do	do	Flouring and grist	7	57½	223	.....
Do	do	do	Meigs	do	7	58+	190	.....
Do	do	do	do	Saw	3	16+	58	.....
Do	do	do	do	Tannery	1	16	14	.....
Do	do	do	Washington	Flouring and grist	6	49	138	.....
Do	do	do	Noble	do	2	14	35	30
Do	do	do	do	Saw	1	6	20	.....
Do	do	do	Monroe	do	2	36	31	16
Do	do	do	do	Flouring and grist	17	163	424	55
Do	do	do	Belmont	do	11	143	236	30
Do	do	do	do	Woolen	1	8	10	.....
Do	do	do	Harrison	Saw	1	24	25	.....
Do	do	do	do	Flouring and grist	6	82	145	84
Do	do	do	Jefferson	do	9	112	158	30
Do	do	do	Columbiana	do	3	50	95	.....
Do	do	Pennsylvania	Beaver	do	1	8	16	.....
Do	do	do	Butler	do	1	9	30	24
Do	do	do	Allegheny	do	1	15	12	12
Do	do	do	do	Hosiery	1	15	8	.....
Do	do	do	do	Flouring and grist	3	32	41	48
Do	do	do	Beaver	do	8	108	137	105
Do	do	do	do	Saw	1	10	15	.....
Do	do	do	Washington	do	4	30	111	30
Do	do	do	do	Flouring and grist	21	215+	482	330
Do	do	do	Greene	do	4	39	122	174
Do	do	West Virginia	Hancock	do	4	59	108	05
Do	do	do	Brooke	do	6	85	141	90
Do	do	do	Ohio	do	5	65	90	30
Do	do	do	Marshall	do	8	83	132	20
Do	do	do	do	Saw	2	32	50	.....
Do	do	do	do	Tannery	1	.....	8	8
Do	do	do	Wetzel	Saw	5	40	150	.....
Do	do	do	do	Flouring and grist	8	67	150	30
Do	do	do	Tyler	do	10	60½	248	.....
Do	do	do	do	Saw	3	20	66	.....
Do	do	do	Pleasant	do	3	.....	60	40
Do	do	do	do	Flouring and grist	3	15+	46	20
488								

WATER-POWER

OF THE

OHIO STATE CANALS.

489—57

WATER-POWER OF THE OHIO STATE CANALS.

Although the writer's examination of water-power in Ohio was limited to that part of the state draining southerly toward the Ohio river, while the principal canals cross not only that portion but also the northern slope, nevertheless it may be proper to give in this report some facts regarding the canal system as a whole. Accurate and detailed data concerning the canals are so scattered among various reports, stretching back over a period of fifty years,(*a*) and upon some points are so entirely lacking, that the most to be attempted will be to convey a general idea as to the history, present condition, value for power, and extent of utilization of these artificial water-ways.

The state canals were constructed in the neighborhood of 1830, and were designed chiefly to afford convenient and cheap communication from the interior of the state to the Ohio river on the south and to lake Erie on the north, and thus to command access to various distant markets. The Ohio canal across the eastern and central portion of the state, and the Miami, connecting with the Wabash and Erie and forming a north-and-south line through the western counties, were the most important of these routes. By the construction of the Hocking canal, the Walhonding, and other minor branches, and by the improvement of the Muskingum river, the system of water-transportation was considerably extended. The numerous state reports belonging to the period of canal construction bear abundant evidence as to the prominent place which these enterprises then held in the public mind; nor, judging from the later history of this great commonwealth, can there be any doubt of the valuable part which they have played in its development. But the position which the canals occupied when they first came into general use has undergone a great relative change. From the condition of being leading highways of traffic, and chief factors in internal growth, they have sunk to that of partial competitors, and to some extent regulators, in the general traffic of the state, heavily handicapped at the same time through certain inherent disadvantages, and in public estimation have come to be judged worthy of only a half-hearted support at the best, and frequently of contempt and neglect.

Some of the small branch canals have never proved profitable, and have from time to time been abandoned, no doubt wisely. The original northern termini of both the Ohio and the Miami and Erie canals have been given up and granted, the former to the city of Cleveland and the latter to Toledo. The southern terminus of the Miami and Erie canal has been cut off for three-quarters of a mile from the Ohio river and granted to Cincinnati, thus severing connection with the river and entailing extra expense upon the transfer of freight from one to the other. The southern outlet of the Ohio canal, also, though nominally open, was practically closed at the time it was visited in January, 1883, by a ruined lock.

Fifty years ago Ohio was a heavily-timbered state, the streams were running fuller than they now do, and the supplying of water to the canals was an easier matter than it has been in late years. To insure sufficient water during the dry seasons, reservoirs, some of them of remarkable size, were constructed in different parts of the state, adjacent to the summit-levels of the canals. With the settlement of the country, its clearing, and more general artificial drainage, the streams have become more uneven in flow than they were before, and the demands upon the reservoirs threaten in some cases to exceed their power to respond. The Licking reservoir, of 3,300 acres, has proven insufficient for the needs of that part of the Ohio canal dependent upon it, and for two months in some years continuous navigation of the latter is impracticable, and lightering has to be resorted to. Even upon the water readily at command a serious and wasteful draught must be made by leaky dams, aqueducts, and locks, in the present inferior condition of the canal works.

When the water-ways we are considering were constructed, there was no thought of railroads as coming competitors. The state was desirous of leasing her surplus waters for power, and did so at what now seem very low rates, usually for periods of ninety-nine years, supposing that by encouraging the location of mills along the canals the business of the latter would thereby be increased. But by the introduction of railroads the routes for shipment have changed, and lessees are enjoying water-privileges at low rates, while the canals do not reap corresponding benefit. Leases of new powers are being issued from time to time, and occasionally some old lease is vacated; in all such cases the state endeavors to obtain new rates that shall be more favorable to her. The total

a Those figures and statements which will hereafter be given are in many instances taken from such sources, and would perhaps require some revision in order to serve for an exact description at the present time; but in the main they are thought to be reliable.

annual rentals received by the state of Ohio on water-power leases are between $50,000 and $60,000, the distribution of which among the different canals, as well as the relation of the income thus derived to that from transportation, may be seen in the following table:

Statement of tolls and fines and water-rents received by the state of Ohio from canals during the year ending November 15, 1880.

[From *Annual Report of Board of Public Works.*]

Name of canal.	Tolls and fines.	Water-rents.
Miami and Erie	$73,061 64	$38,198 03
Ohio	68,703 99	8,841 67
Muskingum improvement (slack-water on Muskingum river)	13,666 93	5,568 65
Hocking	6,489 98	980 47
Walhonding	380 29	.....
Total income from sources mentioned	162,302 83	53,588 82

The leases under which water-rights are enjoyed are variously made out to cover, in some cases, the surplus flowing around a certain lock; in others, water sufficient for a certain number of runs of stones; and, again, a specified number of cubic feet per minute. No suitable means are in use for a measurement, even tolerably approximate, of the amounts of water actually taken by lessees; there is every reason to suppose that they are in many instances largely in excess of the lawful dues, and disputes are frequent. The state reserves a right in all cases to shut off water from lessees for a period of 30 days in the year for the purpose of making repairs to the canals; and also the right of resuming at any time the use of water previously granted or leased, when it shall appear necessary to the interests of navigation, but in the latter instance must compensate the purchaser or lessee.

There are strong reasons for doubting the wisdom of maintaining a system of lease and sale of water-rights in connection with the canals, if these are to be used the most efficiently for navigation. But since the state of Ohio has become so far committed to such a method, it is natural to notice, in the next place, the real value of the powers which thus become available for manufacturing. The power of a privilege is, of course, governed by the amount of water at command and the height of fall through which it can be used. And because, in general, along the canals of Ohio the surplus of water is not very great, nor the fall to be obtained around locks very large, it follows that the powers resulting are to be reckoned for general manufacturing-purposes as only moderate in size, the actual effective powers in use on the Miami and Erie canal averaging about 50 horse-power each, though ranging from 10 to 300, and those on the Ohio canal averaging about 35 horse-power each, with a range from 10 to 150. Those scattered at random along the lines of the canals are suited to flouring-mills of ordinary size, while at a few exceptional points, such as Cincinnati, Dayton, and others, chiefly on the Miami and Erie canal, sufficient power is obtained to support manufacturing of considerable importance.

The main trunks of the Ohio and the Miami and Erie canals were built with a minimum breadth of 40 feet at the water-line and 26 feet at the bottom, with a water-depth of 4 feet. A great part of both canals is of much larger dimensions, having a breadth at water-line of from 60 to 150 feet, and a depth of from 5 to 12 feet, while in some localities even these figures are exceeded. Portions of the canals, however, have become silted up, and their capacity for carrying water has become diminished not only in that way, but also by a thick growth of grass which chokes the channel in summer. The true character of the canals should be kept in mind—that of artificial water-courses, through which there is a slow movement of water toward the points of lowest depression, the supply being introduced at intervals along the course from neighboring streams or reservoirs in order to make up for the losses which are constantly going on through leakage and evaporation, as well as to meet the demands of lockage from one level to another.(*a*)

A greater surplus will evidently be available for power in those portions of the canals below and adjacent to feeders, than farther along where the flow has become so reduced as to need replenishing. The value of the canal powers must depend upon their reliability through the year as well as upon their size. As has been said, they are liable to be cut off thirty days in the year by the state for repairs; they also suffer at many points from diminished flow in summer, when the feeders are low and the channels are choked by grass, and in winter when the water-way is contracted by thick surface-ice or gorged by broken masses. Of the water diverted toward and into the canals much is wasted owing to the leaky condition of the various structures. Nevertheless, it is to be said in favor of canal-privileges that they are usually safe from all danger of freshets, involve no outlay to the users for dams, and offer conveniences for transportation; so that, notwithstanding certain disadvantages, they have important value, and it is not to be wondered at that under the low rentals charged in Ohio they have been very generally occupied for manufacturing-purposes. Although the most desirable powers are already in employment, the state yet holds numerous others, both on the canals and at the dams on the Muskingum improvement, suited to use.

a It was originally estimated that for the Ohio canal, at least, there would be required 100 cubic feet of water per minute per mile, and the maximum velocity of current was placed at 1 foot per second. No accurate data are at hand, however, as to the amounts really furnished or required.

Though it was found practicable to visit but a few of the many privileges utilized along the Ohio and the Miami and Erie canals, a brief description of those examined will perhaps be useful in illustrating what has already been said. The general distribution of the various powers may be learned from the tables elsewhere given, compiled from the census enumerators' returns.

THE OHIO CANAL.

This canal has a length of 309 miles, extending from Cleveland on lake Erie, to Portsmouth on the Ohio river. From the former city it ascends the valleys of the Cuyahoga and Little Cuyahoga rivers, and reaches the north end of the summit-level at Akron, 38 miles from Cleveland. This portion is fed mainly from the Cuyahoga and Little Cuyahoga rivers, and has an ascent of 395½ feet, overcome by means of 44 locks.(*a*) Of these, 21 are within 3 miles, and 16 within 1½ mile of the north end of the summit-level at Akron. Power is utilized by a number of mills, principally at the last-mentioned place.

The canal now enters the basin of the Tuscarawas river, and from the south end of what is known as the Portage summit-level has an uninterrupted descent to Websport, following the Tuscarawas valley and then that of the main Muskingum river. In this distance of 112 miles there is a fall of 238.6 feet, effected by 29 locks. The low level at Websport is also at the foot of a continuous descent from the Licking summit, which lies to the westward, the surplus waters entering it from either direction being discharged through a side-cut into the Muskingum river at Dresden. On the division extending from the Portage summit to Websport and Dresden there are nearly a dozen flouring-mills, using various powers, ranging usually between 15 and 50 horse-power, but in two or three cases reaching 100 and 150. Of these there was visited only the one at Lockport, opposite New Philadelphia, where power is utilized under a fall of 12 feet around a lock at Patterson & Hardy's flouring-mill. Water is taken from above the lock, discharged into the level below, and at times in summer is insufficient for the needs of the mill, which has a capacity for producing 40 barrels of flour daily. For supplying this portion of the canal the Tuscarawas river is drawn upon at Clinton, Zoar, and near the mouth of Stillwater creek; the Walhonding river is drawn upon a few miles above Roscoe, and several minor tributaries of the Tuscarawas also assist.

From the low level at Websport the canal rises to the westward to the Licking summit, making an ascent of 160 feet in the 42 miles by means of 19 locks. The water-supply is derived from the Licking river at the "Narrows", from one or two forks of the main river, and from the Licking reservoir. There are no returns indicating any present use of power on this section of the canal. At Newark there is a fall of 18 feet from the feeder and from the main canal to the water-surface in the North fork of the Licking river, but it is not utilized. In years past the feeder has been employed at Newark for a small woolen-mill, a flouring-mill, and a saw-mill, which did quite an extensive business, but they have one after another abandoned the use of the water-power, the flouring-mill within two or three years, though enjoying at the last exclusive use of the water. The feeder at that point draws from the North fork, and should take its entire low flow; but the feeder-dam is reported as leaky, and the canal has been allowed to silt up, thereby diminishing its capacity, so that the available flow of the stream is not utilized.

From Licking summit the canal runs westerly down the valley of Walnut creek, a tributary of the Scioto river, descending 202¼ feet by means of 30 locks in the 30 miles before it reaches Lockbourne. It receives water in this part of its course from the Licking reservoir, from Little Walnut creek, and from one or two other small streams, and by the Columbus feeder is re-enforced from the Scioto river, which is drawn upon at the above-mentioned city, the feeder running thence southerly about 12 miles, to Lockbourne, with a fall of 14 feet. Several flouring-mills obtain small powers from this section of the Ohio canal, but upon any portion largely dependent upon the Licking summit the supply of water for power must be unreliable.

From Lockbourne the canal takes a southerly direction and continues down the valley of the Scioto river to Portsmouth, at its mouth. In this distance of 87 miles there are 24 locks, and a descent of 211 feet to low water in the Ohio river. The demands of lockage and waste are met by drawing upon the river 2 miles below Circleville, and again 6 miles below Chillicothe. There are small powers in use on this division of the canal by half a dozen or more flouring-mills, two of which will be noticed:

A mile or so above the city Marfield & Massie obtain about 14 feet of fall around two locks. They have the surplus waters from the canal, to which they are limited by a weir built at the entrance of their race to within a few inches of the ordinary water-surface in the canal. The locks are leaky, however, and the firm estimates that half as much water is thus lost as it uses. The mill is a fine one, with twenty-eight sets of rollers and an ordinary capacity for producing 400 barrels of flour in twenty-four hours. This part of the canal is supplied from the Circleville feeder, some 18 miles above, and trouble is experienced in summer from the obstruction of the channel by grass, and in winter from ice. The mill has two overshot wheels, each considered to be of about 20 horse-power with abundant water, but the proprietors estimate that they actually get not over 25 horse-power from the two together, and that for only one-third of the year. Reliance for the balance of the power needed is placed in a steam-engine.

Near the southern terminus of the canal, and about 1½ mile from Portsmouth, George Davis & Co. carry water in a side-cut past two locks and obtain a fall of perhaps 15 feet. They employ a 14-foot wooden

a The locks on the Ohio canal are about 90 by 15 feet in size.

overshot wheel, 12 feet wide, and operate four runs of 4-foot stones, and one double set of rollers. They run their mill twelve hours per day, its capacity being about 50 barrels of flour in that time. Water is drawn from a 6-mile level, and the firm considers the power good for about half the year. From June to September the grass which grows in the canal obstructs the flow of water, and resort is then had to steam-power. In extremely cold weather 8 inches of ice sometimes forms in the canal, and to a considerable extent lessens the flow. At such times the side-cut is liable to become drawn down, the surface-ice in it sinks, and when the water-level rises again the water overruns the ice and freezes; so that when there is 8 inches of ice in the main canal there may be twice that thickness in the side-cut, and the flow is correspondingly interfered with. The wheel also at times becomes covered with a mass of ice which hinders its working.

THE MIAMI AND ERIE CANAL.

This is the most important of the existing canals in Ohio, both with regard to navigation and to use for water-power. From Cincinnati it extends northerly, at a distance ranging from 15 to 35 miles from the western boundary of the state, into Defiance county, where it turns northeasterly and follows down the Maumee river to Toledo. The main trunk has a length of about 246 miles. It originally entered the Ohio river at Cincinnati, and the Maumee river close to its mouth several miles below Toledo; but, as we have elsewhere seen, these termini have been cut off. The section traversed by the canal is fertile, thickly settled, wealthy, enjoys abundant railroad facilities, and has an established character as a manufacturing district. The structures on the Miami and Erie canal appear to be in better condition than those on the Ohio canal, and the hydraulic powers are favored by a generally copious supply of water, derived from the Miami and Maumee rivers and from a system of large reservoirs in the summit-region between their basins. The water-powers along the whole line of the canal are quite generally taken up and in use; this is especially true between Dayton and Cincinnati, and it was stated that probably no more power would be leased along that portion, from danger of interfering with the interests of navigation. The manufacture of flour is an important interest along the entire canal and stands first as regards the number of mills. The paper industry ranks next in this respect, and has been most developed between Dayton and Cincinnati. There are small woolen-mills, also, at various points, as well as saw-mills, machine-shops, agricultural-implement factories, oil-mills, and other works. The greatest utilization of power is found among the three southern counties of Hamilton, Butler, and Montgomery, and in the middle and northern counties of Miami, Auglaize, and Lucas.

At Maumee city, some 8 miles above Toledo, the canal is 63 feet above the level of the Maumee river and lake Erie, and is connected with the former by locks. From this point for 15½ miles, up to the head of the rapids, where the Maumee is rendered tributary for feeding the levels below, there is no lockage. When the canal was built the question of water-power in connection with it was considered, and in the *Sixth Annual Report of the Board of Public Works* (1843), it was stated that "the capacity of this canal is such that from the head of the rapids to Manhattan 18,000 cubic feet of water per minute can be passed and used for hydraulic purposes, without injury to the navigation. At Maumee city the water can be used over a fall of 63 feet; at the locks above Toledo the water can be used over a fall of 49 feet, and at Manhattan over a fall of 15 feet; and between these points the canal is so located that the water can be used from it for hydraulic purposes with great convenience, occupying all the fall between the canal and river". An important amount of power is now in use from this portion of the canal by several paper-mills and large flouring-mills.

From the pool above the rapids the succeeding 26 miles of canal, to Independence, is supplied from the river by means of a dam at that place 9 feet high. From the long level below Independence the report already quoted from mentions an opportunity to utilize a fall of 23 feet to the river. The portion of canal we are now considering was originally known as the Wabash and Erie, being continuous with the Indiana canal of that name. From its junction with the old Miami canal in Paulding county, to the outlet at Toledo on the level of lake Erie, a distance of 64 miles, there is a total descent of 148 feet, effected through 19 locks. This section of the canal was constructed 60 feet wide at top water-line and 6 feet deep. From Paulding county the canal takes a quite direct southerly course, and thence to Dayton, 113 miles below the junction, is utilized at frequent intervals for power by flouring-mills, and occasionally by small woolen factories, saw-mills, and other works, though no details concerning them are at hand other than those furnished by the census enumerators' returns.

At Dayton considerable power is in use on the canal by the Cooper Hydraulic Company. In connection with Mad river the Dayton Hydraulic Company's privilege has already been described, and it has been stated that the water taken by that concern from the river is discharged, after passing through the mills, into the Miami and Erie canal. From the basin into which it is thus discharged it is withdrawn by the Cooper company and utilized under a fall of 12 feet around a lock, being then returned to the canal. At a point below, a certain amount is again withdrawn from the canal, and after it has been employed for power under a fall of 8 feet is discharged into the Miami river. The hydraulic company owns a part of the water, acquired by purchase, and also leases from the state, at an annual rental of $1,000, all the surplus running to supply the levels below Dayton. On this privilege a "run" is defined as 315 cubic feet of water per minute on the "middle", as it is called, or 12-foot fall, and 400 cubic feet per minute on the "lower" or 8-foot fall. A run at the middle fall was originally 300 cubic feet, but, in

consequence of slight backwater, was increased to 315 cubic feet. The rates for both temporary and permanent power vary from $150 to $300 per annum per run, but the larger portion is leased at $200 per annum on the middle and $150 on the lower fall. Water is drawn into the mills through fixed apertures, and is utilized by 4 flouring- and grist-mills, 2 oil-mills, 2 machine-shops, 2 manufactories of agricultural implements, 1 cotton factory, 1 establishment for pulverizing stone, and some other works of small size. One of the lessees has the right to all surplus waters on the privilege, so that the hydraulic company has no more power of which to dispose.

From the basin at Dayton to low water in the Ohio river at Cincinnati, a distance of 66 miles, the canal descends about 300 feet, through 32 locks. Water for feeding the various levels south of Dayton is introduced at that city, Miamisburg, and Middletown. The manufacturing along this section is extensive, the paper and flouring industries being especially prominent. For the former of these as now developed, however, the power furnished from the canal alone is not sufficiently reliable, and the mills are generally fitted with steam-engines for use when the water-supply runs short. Only a few privileges can be noticed in detail:

At Carrollton, 7 or 8 miles below Dayton, George H. Friend & Son have three mills for the manufacture of news, book, manila, and express paper, the aggregate production being from 10 to 15 tons per day. They obtain a fall of 16 feet, and have two water-wheels, each of about 40 horse-power, but generally there is enough water for only one wheel; they operate five steam-engines, and regard steam as their principal motive power. The privilege at this point is considered to have been much better formerly, but is said to have deteriorated through the silting up of the canal and the obstruction of its channel by grass.

At Hamilton, P. Carle & Co. use the surplus passing around a lock, under a fall of 6 feet, to furnish power for their flouring-mill, in which are six sets of rollers. They have water-wheels rated at an aggregate of 100 horse-power, and claim to have sufficient water always, except when it is shut off by the state for repairs.

At Lockland, 12 miles by railroad to the north of Cincinnati, water is taken from a 6-mile level in two races and supplied to mills, which discharge it into the canal again after use. Log weirs prevent the canal-level from being drawn more than 6 inches below its ordinary height. When the canal was built it was considered that there could be spared at this point for hydraulic purposes water sufficient for 12½ runs of stones, and this was divided into three nearly equal parts and leased. The east race runs to a grist-mill. The west race first supplies two paper-mills, one of them owned by the Haldeman Paper Company, under a fall of 14 feet. A fall of 10 feet is then used by the Friend & Fox Paper Company in its printing-paper mill, and from the same level a little surplus is drawn for a small grist-mill. Half a mile farther down the canal the Haldeman company has a second mill. This company manufactures roofing-felt, and various kinds of coarse wrapping-paper, and in addition to rags uses probably 3,000 tons yearly of straw. The latter material is largely employed throughout the Miami valley in paper-manufacture, and, being very extensively produced, is cheaply obtained. For considerable periods it has been purchased at Lockland at as low as $3 per ton, and it was stated by a prominent manufacturer that the average price for a series of years throughout this section was probably about $6 per ton. At Lockland the Haldeman company uses a 61 horse-power water-wheel, but for about three months in winter there is more or less shortage in the supply of water, owing to ice in the canal and race. It forms thick enough to diminish the volume of flow, and this is still further lessened by the breaking up of the ice by boats and its formation in gorges. Water is regarded by the company as its principal power in general, but steam is relied upon at times when the canal supply is insufficient. There was said to be no trouble in this vicinity from grass growing in the canal.

Of the entire rentals received by the state of Ohio from water-leases, about $38,000, or 70 per cent., is derived from those on the Miami and Erie canal, and of this sum nearly $15,000 is paid at Cincinnati. More in detail, fourteen firms and companies north of Brighton pay at Cincinnati $6,193, and seventeen south of Brighton, $8,516. (*a*) The six largest lessees of power, engaged variously in the manufacture of paper, flour, cotton, and oil, pay rentals ranging from $2,200 down to $1,000, while other lessees pay sums ranging thence down to $25.

From the upper plane of the city of Cincinnati the canal descended formerly to the Ohio by means of 10 locks, with a fall of 111 feet, measured to low water in the river. This terminal portion, though abandoned for navigation, is nevertheless utilized for power. Much of the way it is covered from view, and in part of its course the water is divided between two separate channels. Water is used successively from one level to another, and is finally discharged into the Eggleston Avenue sewer. The power here was mainly leased from 1831 to 1834, and for periods of 99 years. The leases are considered valuable, the rentals being moderate, and are not allowed to lapse from any cause. At some of the mills there are said to be weirs of stone to govern the admission of water, but in general none are in use. There is no regulating weir at the upper fall even, and when the canal becomes drawn down too far the mills are shut off. This has sometimes to be done for a few hours, occasionally for as long as half a day. In winter more or less trouble is experienced from the clogging of the canal by ice, and, as it is claimed by the millers, from the withdrawals at points along its course to fill ice-ponds. From the statements made by several of the larger manufacturers, it is judged that for about two months in the year the supply of water at their mills is, from various causes, curtailed. The principal use of power at Cincinnati from the canal is by five flouring-mills, an elevator, a linseed-oil factory, a cotton-mill, a carriage factory, and an establishment for the manufacture

a Figures as given by Mr. John B. Gregory, chief engineer of the state, in January, 1883.

of hydraulic machinery. Messrs. Whetstone & Co. manufacture linseed oil, using for that purpose about 80,000 bushels of seed annually. Gould, Pearce, & Co. run about 15,000 cotton-spindles, making no cloth, but sundry goods which might be classed as notions—lamp-wicks, shoe-strings, and other articles.

Table of utilized power on the Ohio state canals.

Canal.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized. (a)	Total water-power utilized.	Auxiliary steam-power.
				Feet.	*H. P.*	*H. P.*
Hocking	Fairfield	Flouring and grist	1	10	25	.....
Do	Hocking	Saw	1	8	20	.....
Miami and Erie	Hamilton	Carriages and wagons	1	.....	.....	.....
Do	...do	Cotton	1	11½	60	60
Do	...do	Elevator	1	.....	.....	.....
Do	...do	Flouring and grist	6	70½	305	80
Do	...do	Gold pens	1	.....	15	15
Do	...do	Machinery	1	11	40	.....
Do	...do	Oil	1	.....	.....	.....
Do	...do	Paper	5	66	276	425
Do	Butler	Flouring and grist	3	17	219	.....
Do	...do	Paper	7	52½	683	336
Do	...do	Saw	1	5	11	.....
Do	Montgomery	Agricultural implements	2	Two falls, 12 and 8 feet.	b 320+	b 215
Do	...do	Cotton	1			
Do	...do	Flouring and grist	4			
Do	...do	Kaolin and ground earths	1			
Do	...do	Linseed oil	2			
Do	...do	Machinery	2			
Do	...do	Varnish	1			
Do	...do	Woolen	2			
Do	...do	Flouring and grist	5	37	142	.....
Do	...do	Paper	1	16	80	300
Do	...do	Saw	2	7+	27	.....
Do	Miami	Flax, dressed	1	10	35	.....
Do	...do	Flouring and grist	8	68	359	.....
Do	...do	Linseed oil	1	10	25	.....
Do	...do	Woolen	1	10	40	40
Do	Shelby	Agricultural implements	1	10	10	.....
Do	...do	Saw	1	24	60	.....
Do	Auglaize	Flouring and grist	6	66	235	95
Do	...do	Saw	4	30+	90	.....
Do	...do	Vegetable oil	1	16	35	.....
Do	...do	Wooden handles	1	16	25	40
Do	...do	Woolen	2	23	47	60
Do	Allen	Flouring and grist	2	17	62	.....
Do	...do	Lumber, planed	1	8	17	.....
Do	...do	Saw	1	9	41	.....
Do	...do	Woolen	1	10½	35	.....
Do	Van Wert	...do	1	8½	15	.....
Do	...do	Paper	1	6	28	60
Do	Putnam	Flouring and grist	1	9	52	.....
Do	Paulding	...do	1	24	50	.....
Do	Defiance	...do	2	23	140	65
Do	...do	Machinery	1	14	30	30
Do	...do	Wooden packing-boxes	1	10	24	.....
Do	...do	Woolen	1	18	21	.....
Do	Henry	Flouring and grist	2	32	58	.....
Do	...do	Saw	1	18	30	.....
Do	...do	Tannery	1	18	15	.....
Do	...do	Wooden handles	1	18	15	.....
Do	Lucas	Agricultural implements	1	17	48	.....
Do	...do	Flouring and grist	5	87	800	.....
Do	...do	Paper	3	60	260	.....
Do	...do	Saw	1	16	25	.....
Ohio	Cuyahoga	Drugs and chemicals	1	6	12	10
Do	...do	Flouring and grist	1	8	47	.....
Do	Summit	...do	1	8½	14	40
Do	...do	Pumps	1	7	15	25
Do	...do	Saw	2	14	30	40
Do	...do	Tannery	1	12	20	16

a In this column the same fall is, doubtless, in some cases counted more than once, the census enumerators' returns not indicating clearly whether several mills in a township are located all upon one privilege or upon separate privileges.

b Dayton. Cooper hydraulic canal (returns incomplete).

Table of utilized power on the Ohio state canals—Continued.

Canal.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.
				Feet.	*H. P.*	*H. P.*
Ohio	Summit	Tobacco-pipes	1	3	20	20
Do	Stark	Flouring and grist	2	16	55	30
Do	....do	Boats	1	13	30	.....
Do	Tuscarawas	Woolen	1	3½	15	.....
Do	....do	Flouring and grist	5	42½	268	.....
Do	Coshocton	....do	2	16	55	.....
Do	....do	Iron castings and finishings	1	9	10	.....
Do	....do	Saw	1	12	27	.....
Do	Muskingum	Woolen	1	4	20	.....
Do	....do	Flouring and grist	3	49	340	.....
Do	Fairfield	....do	3	36	66	40
Do	Franklin	....do	2	34	110	105
Do	Pickaway	....do	1	20	40	.....
Do	Ross	....do	2	22	68	40
Do	....do	Saw	1	15	16	.....
Do	Pike	Flouring and grist	4	48	101	.....
Do	Scioto	....do	2	23	75	80
Walhonding	Coshocton	....do	2	38	165	.....
Do	....do	Iron castings and finishings	1	9	4	.....
Do	....do	Woolen	1	21	45	.....

Summary of utilized power on certain

[Embracing all tributaries on the north above and including the Great Miami

	River.	WOOLEN-MILLS.			PAPER- AND WOOD-PULP MILLS.			FLOURING- AND GRIST-MILLS.		
		Number.	Total water-power utilized.	Auxiliary steam-power.	Number.	Total water-power utilized.	Auxiliary steam-power.	Number.	Total water-power utilized.	Auxiliary steam-power.
			H. P.	*H. P.*		*H. P.*	*H. P.*		*H. P.*	*H. P.*
	Ohio state canals	11	278	100	17	1,327	1,121	76	3,934	750
1	Allegheny river and tributaries	27	386	40	3	400+	.....	293	8,571	1,924
2	Monongahela river and tributaries	12	141	82	2	450	150	197	4,036	1,538
3	Beaver river and tributaries	13	160	20	1	40	12	96	3,026	1,011
4	Muskingum river and tributaries	15	248	20	.....	.....	.....	178	5,646	1,330
5	Little Kanawha river and tributaries	.....	.....	.....	.....	.....	.....	24	462	16
6	Scioto river and tributaries	7	146	30	2	165	120	80	2,193	641
7	Great Miami river and tributaries	15	221	75	20	1,950+	1,760	167	5,541	402
8	Sundry small streams	5	69	6	1	55	50	260	6,380	1,720
	Total, aside from Ohio canals	94	1,371	273	29	3,060+	2,092	1,295	35,855	8,582
	Total, including Ohio canals	105	1,649	373	46	4,387+	3,213	1,371	39,789	9,332

a Comprising steel works, machine-shops, blacksmith-shops, and works for the manufacture of agricultural implements, axes, cutlery and edge-tools, hardware;

b Comprising carpenter, wheelwright, and cooper shops, and concerns for the manufacture of beehives, carriage and wagon materials; coffins, burial-cases, and barrows.

c Comprising cotton-mills (2), knitting-mills, bakeries, flax-dressing works, marble- and stone-works potteries, pumping works for water-supply, scouring compounds, butter and cheese.

tributaries of the Ohio river.

river, and all tributaries on the south above and including the Little Kanawha river.]

SAW-MILLS.			METAL-WORKING ESTABLISHMENTS. (a)			WOOD-WORKING ESTABLISHMENTS. (b)			SUNDRY OTHER ESTABLISHMENTS. (c)			TOTAL.			
Number.	Total water-power utilized.	Auxiliary steam-power.	Number.	Total water-power utilized.	Auxiliary steam-power.	Number.	Total water-power utilized.	Auxiliary steam-power.	Number.	Total water-power utilized.	Auxiliary steam-power.	Number.	Total water-power utilized.	Auxiliary steam-power.	
	H. P.	*H. P.*		*H. P.*	*H. P.*		*H. P.*	*H. P.*		*H. P.*	*H. P.*		*H. P.*	*H. P.*	
16	377	40	12	275	110	6	111	40	15	316+	106	153	6,618+	2,267	
341	8,899	968	10	323	141	32	533	20	13	228	25	719	19,340+	3,118	1
66	1,052	18	.....	.....	.....	5	38	.....	5	78	.....	287	5,795	1,788	2
20	380	45	13	400	245	12	411	75	8	185	200	163	4,602	1,608	3
49	996	98	3	52	12	7	108	48	1	16	.....	253	7,066	1,508	4
3	47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	27	509	16	5
27	504	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	116	3,008	791	6
46	897	12	19	435	165	14	221	158	11	224	22	292	9,489+	2,594	7
57	1,314	142	.....	.....	.....	2	24	.....	5	250	208	330	8,092	2,126	8
609	14,089	1,283	45	1,210	563	72	1,335	301	43	981	455	2,187	57,901+	13,549	
625	14,466	1,323	57	1,485	673	78	1,446	341	58	1,297+	561	2,340	64,519+	15,816	

iron nails, spikes, etc.; iron castings and finishings; pumps, rivets, steam-drills, turbines, and wire.
undertakers' goods; furniture, lead-kegs, pianos; sashes, doors, and blinds; shingles, staves; washing-machines and clothes-wringers; wooden handles, and wheel-

works, tanneries, and establishments for the manufacture of baskets, cordage and twine, cider, oil, gunpowder, high explosives, hosiery, patent medicines and

INDEX TO REPORT ON WATER-POWER OF THE OHIO RIVER BASIN.

A.

Page.

Allegheny river—
- Altitudes on various tributaries of 14
- And tributaries, table of utilized power on 18-21
- Development of resources of region tributary to 9
- Discharge of 10
- Drainage areas of 8
- Drainage areas of tributaries of 14
- Estimate of power at principal ripples on, between Olean and Warren 13
- Fall in, amount and distribution of, unfavorable 9, 10
- Fall in, table showing amount of 10
- Manufacturing by water-power on course of 11-13
- Navigation of, and proposed improvement 9
- Topography of basin of 9
- Tributaries of 13-18

Apron, action of, in protecting dam 50

B.

Backwater from Ohio river, hindrances caused by, to hydraulic powers at mouth of Muskingum river 37, 38

Beaver Falls, Pennsylvania—
- Estimate of power at 32
- Manufacturing works at 31

Beaver river—
- And tributaries, elevations on 31
- And tributaries, table of utilized power on 33, 34
- Backwater in lower course of, from Ohio river 31
- Drainage areas of 30
- Fall from New Castle to mouth of 31
- Former system of slack-water navigation on 31
- Valuable deposits of coal and iron in basin of 30
- Water-powers on main course of 31, 32

Bluestone, Cheat river 26

Bottom-land along lower course of Scioto river, character of 44

C.

Canals, Ohio state—
- Altered position and influence of 59
- But little supervision exercised over lessees of power on 60
- Causes affecting value of powers on 60
- Conditions under which power was originally leased on 59
- Depletion of water-supply for 59
- History of 59
- Magnitude of powers in use on 60
- Revenues derived from, in 1880 60
- Table of utilized power on 64, 65

Carrollton, Ohio, power on Miami and Erie canal, at 63

Castleman's river 26

Chautauqua lake—
- Drainage areas of outlet of 15
- Restrictions upon withdrawals from, for hydraulic power 15

Cheat river—
- Estimate of power on, at Rowlesburg, West Virginia 27
- Extent of drainage basin of 26
- Fall in 26
- Lumber industry on course of 26
- Rapid fluctuations in volume of 26
- Value of, for water-power 26

Cincinnati, Ohio, power on Miami and Erie canal at 63, 64

Clarion river, discharge of 13

Clarksburg, West Virginia—
- Construction of dam on West fork of Monongahela river at 28
- Estimate of power at 28

Page.

Coke, manufacture of, in valley of Youghiogheny river 24

Conewango creek 14, 15
- Descent in 15

Conneaut lake, former use of, as storage-reservoir for supply of Erie canal of Pennsylvania 16

Connellsville, Pennsylvania—
- Characteristics of Youghiogheny river above 25
- Estimate of power at 24

Corydon, Pennsylvania—
- Estimate of power of Allegheny river at 13
- Features of river below 13
- Manufacturing works at 12, 13

D.

Dam in—
- Beaver river at New Brighton, cost of 32
- Great Miami river at Dayton View, construction of 51
- Great Miami river at Franklin, failure of 50
- Great Miami river at Middletown, failure of 49
- Mad river near Dayton, construction of, and injury to, from ice 52, 53

Dam, movable, in Ohio river at Davis island—
- Description of 5, 6
- Surplus power available at 6

Dam, pile, in Allegheny river—
- At Salamanca, New York, description of 12
- Near Olean, New York, description of 11

Dams built by Monongahela Navigation Company—
- Construction of 23
- Injuries to, from freshets and ice 23

Dams in—
- Muskingum river, general type of construction of 36, 37
- Youghiogheny river, destroyed by ice 24

Darby creek, Ohio 44

Dayton, Ohio—
- Manufacturing works supplied from Dayton Hydraulic Company's canal at 53
- Power on Mad river at 52, 53
- Power on Miami and Erie canal at 62, 63

Dayton View, Ohio—
- Estimate of power on Great Miami river at 52
- Surplus power still available at 52

Deer creek, Ohio 44

Discharge of—
- Allegheny river 10
- Clarion river 13
- French creek 16
- Kiskiminetas river 13
- Mad river 47
- Miami river 47
- Ohio river at Louisville 7
- Scioto river 44, 45
- Streams in Ohio River basin, relatively to rainfall 5
- Youghiogheny river at Ohio Pile falls 25

Drainage areas of—
- Allegheny river 8
- Beaver river and tributaries 30
- Chautauqua outlet and Conewango creek 15
- Great Miami river and tributaries 52
- Little Kanawha river and tributaries 42
- Monongahela river and tributaries 23
- Muskingum river and tributaries 34
- Scioto river and tributaries 45
- Tributaries of Allegheny river 14

E.

Page.

Elevation of country at headwaters of Great Miami river 47
Elevations on—
Beaver river and principal tributaries 31
Tributaries of Allegheny river 14
(See, also, tables of fall.)
Erie canal of Pennsylvania, former connection of, with French creek ... 16
Estimate of power of—
Allegheny river at Corydon 13
Allegheny river at principal ripples between Olean and Warren ... 13
Allegheny river at Salamanca 12
Beaver river at Beaver Falls 32
Beaver river at New Brighton and Fallston 32
Cheat river at Rowlesburg 27
French creek at Franklin 17
French creek at Meadville 17
Great Miami river at Dayton View 52
Great Miami river at Franklin 51
Muskingum river at state dams 38
Ohio river at Louisville 8
Tygart's Valley river at Valley Falls 27
West fork of Monongahela river at Clarksburg 28
Youghiogheny river at Connellsville 24
Youghiogheny river at Ohio Pile falls 25

F.

Fairmount, West Virginia, power in use on Monongahela river at 21
Fall at dams in Monongahela river 23
Fall, table showing, in—
Allegheny river 10
French creek 16
Great Miami and Mad rivers 47
Little Kanawha river 42
Monongahela river and tributaries 22
Muskingum river and tributaries 36
Ohio river 6
Scioto river 44
Falls—
Of Licking 40
Of the Ohio at Louisville 7, 8
Ohio Pile, in Youghiogheny river 25
Falls City, Pennsylvania, power at (see Ohio Pile falls) 25, 26
Fallston, Pennsylvania, power on Beaver river at 32
Franklin, Ohio—
Construction of dam in Great Miami river at 50
Estimate of power at 51
Rental charged for power at 50
Surplus power available for manufacturing at 51
Franklin, Pennsylvania, power on French creek at 17, 18
French creek—
Agricultural value of land in basin of 16
Freshet rises in, and effect upon, of clearing of country 15
Table showing fall in 16
Volume of flow in 16
Water-powers on, at Meadville and Franklin 17, 18
Freshets—
Backwater from, in Ohio river, submerges lower dams on Beaver river 31
Cause occasional submergence of valley of French creek 16
Dangerous character of, in Youghiogheny river 24
Heavy and violent, in Monongahela river 21, 23
Heights of, in lower Scioto river 44
Heights of, in Ohio river 7
Heights of, in upper Allegheny river 11
In Great Miami river 48
In Little Kanawha river, rapid and great oscillations during 43
Rapid fluctuations in volume of Cheat river from 26

G.

Great Miami river—
And tributaries, drainage areas of 52
And tributaries, table of utilized power on 53–55
Cost of water-power in valley of 48
Development of paper manufacturing in valley of 46
Discharge of 47
Extent to which fall of, has been utilized 48
Fall in course of 47

Great Miami river—Continued. Page.
Features contributing to value of, for power 47
Water-powers on 48–52

H.

Hamilton, Ohio—
Manufacturing works at 49
Power on Great Miami river at 48, 49
Rate charged for power at 49
Hydraulic Company—
Cooper 62
Dayton 52
Dayton View 52
Franklin 50
Hamilton and Rossville 48
Miamisburg 51
Middletown 49
West Hamilton 49

I.

Ice—
Dangers from gorges of, in Allegheny river 11
Injuries caused by, to dams on Monongahela river 23
Occurrence of, in Youghiogheny river 24
Indian reservations on course of Allegheny river 12

J.

Jamestown, New York, manufacturing by water-power at, on outlet of Chautauqua lake 15

K.

Kiskiminetas river, discharge of 13

L.

Lagonda creek, Ohio 53
Licking, falls of, opportunity for development of power at 40
Licking river—
Drawn upon for feeding Ohio canal 40
Powers on, at Zanesville and above 40
Little Kanawha river—
And tributaries, table of utilized power on 43
Drainage areas of 42
Fall of 42
Rapid fluctuations in 43
Slack-water navigation on 42
Surplus power available at dams in 42
Unfavorable geological character of country drained by 43
Lockland, Ohio, power utilized on Miami and Erie canal at 63
Louisville—
Amount of power possibly available at 8
General description of river at falls at 7
Leading designs for development of power at 7
Variations in fall of river at 8
Lumber—
Amount of, sawed on Allegheny river near Olean and at Salamanca. 11, 12
Amount of, sawed on Cheat river at Rowlesburg 26
Manufacture of, the chief industry on the Little Kanawha river ... 42

M.

Mad river—
Descent in 47
Discharge of 47
General features of 52
Water-powers on, at Dayton and above 52, 53
Marietta and Harmar, power on Muskingum river at 37, 38
Meadville, Pennsylvania—
Character of French creek below, as regards water-power 17
Power at 17
Miami and Erie canal—
Advantageous falls on 62
Description of certain powers on, at Carrollton, Cincinnati, Dayton, Hamilton, and Lockland 62–64
Favorable to utilization of hydraulic power 62
Principal manufacturing industries on line of 62
Rentals yielded to state of Ohio by 63
Miamisburg, Ohio—
Manufacturing interests sustained by water-power at 51
Permanent power all leased at 51
Middletown, Ohio—
Establishments employing power at 49

Page.

Middletown, Ohio—Continued.
- Rental charged for power at ... 49
- Surplus power for lease at ... 50

Mill-stone power, equivalents of ... 49
Monongahela Navigation Company ... 22, 23
- Description of works built by ... 23

Monongahela river—
- And principal tributaries, drainage areas of ... 23
- And principal tributaries, table showing fall in ... 22
- And principal tributaries, table of utilized power on ... 29, 30
- Freshet rise in, at Fairmount ... 21
- History of navigation improvements on ... 22
- Small powers utilized on, at Fairmount and Port Perry ... 21, 22
- Surface features of country drained by ... 21
- System of locks and dams on ... 22, 23

Monongahela river, West fork of—
- Heavy droughts in basin of ... 28
- Resources of region tributary to ... 28
- Utilization of power on ... 28

Muskingum river—
- Agricultural and mineral resources of section drained by ... 34
- And principal tributaries, drainage areas of ... 34
- And tributaries, table of utilized power on ... 40, 41
- And tributaries, table showing elevations on ... 36
- Conditions under which water is leased on course of, by state ... 37
- Elevation of northern water-shed of ... 34
- Estimate of power at state dams on ... 38
- Important towns on banks of ... 36
- Slack-water navigation on ... 36
- Streams in basin of, drawn upon for feeding Ohio canal ... 35
- Tributaries of ... 38–40
- Water-power on, at state dams ... 36, 38

N.

New Brighton and Fallston—
- Estimate of power on Beaver river at ... 32
- Manufacturing industries at ... 32
- Surplus power still available at ... 32

O.

Ohio canal—
- Amount of lockage in ... 61
- Obstructions in, caused by grass and ice ... 62
- Sources of water-supply for feeding ... 61
- Water-powers utilized on, near New Philadelphia, Chillicothe, and Portsmouth ... 61, 62

Ohio Pile falls—
- Estimate of power of Youghiogheny river at ... 25
- Manufacturing works now in operation at ... 25
- Nature of river above ... 26
- Report upon water-power at, made in 1825, by government commission ... 25

Ohio river—
- Course of water-shed lines of ... 3
- Data concerning fall, navigation, etc., of principal tributaries of ... 4
- Davis Island dam in, description of ... 5, 6
- Elevations on, table of ... 6
- Floods in ... 7
- General features of tributaries of, as regards water-power ... 4, 5
- Power at Louisville on ... 7, 8
- Power utilized on various minor tributaries of, table of ... 55, 56
- Slope, width, and navigation of ... 6
- Summary of power utilized on certain tributaries of ... 66, 67
- Topography of basin of, and influence upon character of tributary streams ... 3
- Utilization of power on, in general impracticable ... 6

Olean, New York, utilized powers on Allegheny river near ... 11
Olentangy river, Ohio ... 44

P.

Paint creek, Ohio ... 44
Paper—
- Advantages offered by Miami River valley for manufacture of ... 46, 47
- Fine writing, manufactured at Franklin, Ohio ... 50
- Statistics of manufacture of, in Miami River valley ... 46

R.

Rainfall, records of, at points in Ohio River basin ... 5
Regulating delivery of water for hydraulic power, method of—
- Employed on Beaver river at New Brighton and Fallston ... 32

Page.

Regulating delivery of water for hydraulic power, method of—Cont'd.
- Employed at certain points on Great Miami and Mad rivers ... 49, 53
- Prescribed for water-privileges at state dams on Muskingum river ... 37

Rentals charged for power by—
- Hydraulic companies in Miami River valley ... 48
- State of Ohio at dams in Muskingum river, lack of uniformity in ... 37

Reservoir—
- Licking, description of ... 36
- Saint Mary's, size and cost of ... 36, 47

Reservoirs, storage—
- Of large size, constructed for supplying canals of Ohio ... 36
- Practicability of, in connection with hydraulic power, in Ohio ... 35

Rock, peculiar distribution of, in bed of Little Kanawha river ... 42, 43
Rowlesburg, West Virginia, estimate of power of Cheat river at ... 27
Run of water, equivalents of, at points in Miami River valley ... 49, 50, 52, 53, 62, 63

S.

Salamanca, New York, power on Allegheny river at ... 12
Scioto river—
- And tributaries, drainage areas of ... 45
- And tributaries, table of utilized power on ... 45, 46
- Country at headwaters of, unfavorable to uniformity of discharge ... 43
- Course of Ohio canal within basin of ... 45
- Dry season discharge of, very small ... 44, 45
- Geological features of valley of ... 44
- State dams in ... 45
- Table showing fall in ... 44

Snowfall, heavy, in upper basin of Allegheny river ... 11
Straw suitable for manufacture of paper abundant and cheap in Miami River valley ... 63

T.

Temperature, records of, at points in Ohio River basin ... 5
Transportation, effect of changed conditions of, on value of water-power on Muskingum river ... 37
Tuscarawas river ... 38, 39
- Water-power utilized on, at New Philadelphia and other points ... 39

Tygart's Valley river—
- Area of country drained by ... 27
- General characteristics of ... 27
- Importance of lumber industry on ... 28
- Water-powers on lower course of ... 27

V.

Valley Falls, West Virginia, water-power on Tygart's Valley river at ... 27

W.

Walhonding canal, available power on ... 39
Walhonding river ... 39
Walnut creek, Big ... 44
Water-power, table of utilized, on—
- Allegheny river and tributaries ... 18–21
- Beaver river and tributaries ... 33, 34
- Great Miami river and tributaries ... 53–55
- Little Kanawha river and tributaries ... 43
- Monongahela river and tributaries ... 29, 30
- Muskingum river and tributaries ... 40, 41
- Ohio State canals ... 64, 65
- Scioto river and tributaries ... 45, 46
- Summary for certain tributaries of Ohio river ... 66, 67
- Various minor tributaries of Ohio river ... 55, 56

Wills creek, Ohio ... 40

Y.

Youghiogheny river—
- Former existence of slack-water navigation on ... 24
- Occurrence of ice-runs in, and resulting destruction of dams ... 24
- Principal industry of valley of ... 24
- Water-powers on, at Connellsville and Ohio Pile falls ... 24–26

Z.

Zanesville, Ohio—
- Disadvantages encountered in use of water-power at ... 38
- Power on Licking river at ... 40
- Power on Muskingum river at ... 38

REPORT

ON THE

WATER-SUPPLY OF CERTAIN CITIES

OF

THE UNITED STATES,

COMPILED UNDER THE DIRECTION OF

PROF. W. P. TROWBRIDGE,

CHIEF SPECIAL AGENT IN THE DEPARTMENT OF POWER AND MACHINERY EMPLOYED IN MANUFACTURES,

BY

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SPECIAL AGENT TENTH CENSUS.

TABLE OF CONTENTS.

	Page.
LETTER OF TRANSMITTAL	ix
INTRODUCTION	1–3
Water-pipes	1, 2
Filtering basins	2
Comparison of Systems	2
Purity of Waters	3
Illustrations	3
1. GRAVITY SUPPLY	5–45
New York, N. Y	5–17
Boston, Massachusetts	17–31
The Mystic department	24, 25
Additional supply of water	25–27
The Parker Hill distributing reservoir	28–30
Hartford, Connecticut	32–34
Springfield, Massachusetts	34–38
New London, Connecticut	38–40
Portland, Maine	40, 41
Norwich, Connecticut	41–43
Concord, New Hampshire	43, 44
Rutland, Vermont	44, 45
2. DIRECT PUMPING	46–56
Indianapolis, Indiana	46, 47
Columbus, Ohio	47–50
Burlington, Iowa	50–55
Peoria, Illinois	56
3. PUMPING TO STAND-PIPE	57–69
Bloomington, Illinois	57, 58
Sandusky, Ohio	58–62
Toledo, Ohio	62–65
Detroit, Michigan	65–69
Chicago, Illinois	69
4. PUMPING THROUGH STAND-PIPE—SURPLUS TO RESERVOIRS	70–77
Providence, Rhode Island	70–77
5. PUMPING THROUGH STAND-PIPE TO RESERVOIRS	78–82
Nashville, Tennessee	78, 79
Louisville, Kentucky	80–82
6. PUMPING DIRECT TO RESERVOIRS	83–117
Brooklyn, New York	83–90
Pittsburgh, Pennsylvania	90–94
Albany, New York	94–96
New Haven, Connecticut	97–99
Salem, Massachusetts	99–101
Cincinnati, Ohio	101–111
Cleveland, Ohio	112–113
Lowell, Massachusetts	114–117
7. PUMPING BY WATER-POWER	118–124
Manchester, New Hampshire	118–122
Bangor, Maine	122–124
8. COMBINATIONS	125–171
Philadelphia, Pennsylvania	125–144
The Fairmount works	127–131
The Schuylkill works	131–134
The Belmont works	134, 135
The Delaware works	135–137
The Frankford works	137–139
The Roxborough works	139–141
The Chestnut Hill works	141

COMBINATIONS—Continued. Page.
SAINT LOUIS, MISSOURI 144–152
NEW ORLEANS, LOUISIANA 153, 154
ROCHESTER, NEW YORK 154–160
TROY, NEW YORK 160–163
PAWTUCKET, RHODE ISLAND 163–167
POUGHKEEPSIE, NEW YORK 167–171

OTHER WATER-WORKS.

GRAVITY SYSTEM 173–194
CALIFORNIA 173–175
Dutch Flat—Grass Valley—Los Angeles—Mission San José—Oakland—Petaluma—Placerville—San José—San Rafael—Santa Barbara—Santa Clara—Truckee—Washington—Watsonville—Yreka.
COLORADO 175
Caribou—Colorado Springs 175–178
CONNECTICUT .....
Ansonia—Bethel—Birmingham—Danbury—Greenwich—Meriden—New Britain—New Milford—Rockville—Shelton—Simsbury—South Norwalk—Stamford—Waterbury—West Winsted—Windsor—Wolcottville.
DAKOTA 178
Deadwood.
GEORGIA 178
Macon.
MAINE 178
Auburn—Skowhegan—Springvale.
MARYLAND 178
Frostburg.
MASSACHUSETTS 178–183
Agawam—Arlington—Athol—Chicopee—Fitchburg—Greenfield—Hingham—Holyoke—Leominster—Malden—Medford—Melrose—Northampton—Northfield—Peabody—Pittsfield—South Adams—Southbridge—South Hadley Falls—Stockbridge—Uxbridge—Westborough—Westfield—West Springfield—West Stockbridge—Williamstown—Winchester—Worcester.
MICHIGAN 183
Niles.
MINNESOTA 183
Saint Paul.
NEVADA 183, 184
Austin—Eureka—Pioche—Reno—Virginia City.
NEW HAMPSHIRE 184
Bethlehem—Dover—Hanover—Keene—Portsmouth.
NEW JERSEY 184
Morristown.
NEW YORK 184–187
Attica—Avon—Delhi—Ellenville—Geneva—Glens Falls—Gloversville—Goshen—Malone—Middletown—Mount Morris—Newburg—Plattsburg—Port Jervis—Richfield Springs—Utica—Walton—Warsaw—Warwick—Waverly.
NORTH CAROLINA 187
Fayetteville.
OHIO 187, 188
New Lisbon—Wooster.
OREGON 188
Dallas.
PENNSYLVANIA 188–193
Altoona—Archbald—Ashland—Canton—Carbondale—Coatesville—Downington—Dunmore—Ephrata—Franklin—Gettysburg—Hanover—Hazleton—Hollidaysburg—Johnstown—Lebanon—Mahanoy City—Mechanicsburg—Minersville—Plymouth—Pottsville—Reading—Renovo—Scranton—Sewickley—Slatington—Stroudsburg—Susquehanna—Tidioute—Towanda—Tremont—Tunkhannock—Wilkesbarre—Williamsport.
RHODE ISLAND 193
Westerly.
UTAH 193
Logan—Salt Lake City.
VERMONT 193, 194
Bellows Falls—Brandon—Fair Haven—Saint Albans.
VIRGINIA 194
University of Virginia—Winchester.
WASHINGTON TERRITORY 194
Walla-Walla.
WISCONSIN 194
Fond du Lac—Kenosha—Prairie du Chien.
PUMPING TO DISTRIBUTING RESERVOIRS 195–211
CALIFORNIA 195
Marysville—San Diego.
COLORADO 195, 196
Cañon City—Trinidad.

PUMPING TO DISTRIBUTING RESERVOIRS—Continued. Page.
DELAWARE 196
New Castle—Wilmington.
GEORGIA 196
Rome.
ILLINOIS 196, 197
De Kalb—Lockport—Quincy.
INDIANA 197, 198
Attica—Fort Wayne—La Fayette—New Albany.
KENTUCKY 198, 199
Maysville—Newport—Pleasant Hill.
MAINE 199
Biddeford—Lewiston.
MASSACHUSETTS 199-201
Danvers—Kingston—Lincoln—Lynn—Somerville—Waltham.
MISSOURI 201
Saint Joseph.
NEW HAMPSHIRE 201
Nashua.
NEW JERSEY 201-203
Bridgeton—Cape May—Jersey City—Mount Holly—Passaic—Paterson—Trenton.
NEW YORK 203, 204
Cohoes—Hudson—Lyons—Oswego—Peekskill—West Troy.
OHIO 204, 205
Bellaire—East Liverpool.
PENNSYLVANIA 205-210
Allegheny—Butler—Carlisle—Chester—Clarion—Harrisburg—Kennett Square—Kittanning—Lancaster—Meadville—Mount Joy—Norristown—Oil City—Oxford—Parker's Landing—Phœnixville—Pittston—Saint Petersburg—Summit Hill—Westchester—York.
TENNESSEE 210
Chattanooga.
TEXAS 210, 211
Austin.
VERMONT 211
Burlington.
VIRGINIA 211
Danville.
PUMPING TO STAND-PIPE 212-215
ARKANSAS 212
Little Rock.
GEORGIA 212
Augusta—Savannah.
INDIANA 213
South Bend—Terre Haute.
MASSACHUSETTS 213, 214
Fall River—Nantucket.
NEW JERSEY 214
Belvidere—Millville.
OHIO 214
Lancaster.
PENNSYLVANIA 214
Bristol.
SOUTH CAROLINA 214, 215
Charleston.
TEXAS 215
Dallas.
PUMPING DIRECT INTO DISTRIBUTING MAINS 216-233
CALIFORNIA 216
Chico—Sacramento.
COLORADO 216, 217
Denver—Pueblo.
GEORGIA 217
Atlanta.
ILLINOIS 217-219
Decatur—Geneseo—Hyde Park—Lake—Moline—Ravenswood—Rochelle—Stockyard Station—Sycamore.
INDIANA 219-221
Brazil—Columbus—Connersville—Evansville—Logansport—Marion—Union City.
IOWA 221, 222
Cedar Rapids—Davenport—Des Moines—Keokuk—Marengo—Marshalltown—Monticello—Oskaloosa.
KANSAS 222, 223
Emporia.

PUMPING DIRECT INTO DISTRIBUTING MAINS—Continued. Page.
KENTUCKY 223
Owensborough.
MASSACHUSETTS 223
Taunton.
MICHIGAN 223-226
Allegan—Alpena—Bay City—Big Rapids—Cadillac—Constantine—East Saginaw—Holly—Jackson—Marquette—Muskegon—Port Huron—Saginaw—Saint Louis.
MINNESOTA 226
Mankato—Minneapolis.
NEW JERSEY 226, 227
Rahway.
NEW YORK 227-230
Auburn—Batavia—College Point—Cooperstown—Dunkirk—Garden City—Gouverneur—Jordan—Lockport—Long Island City—Niagara Falls—Ogdensburg—Olean—Potsdam—Saratoga Springs—Schenectady.
OHIO 230-232
Dayton—Ironton—Mansfield—Norwalk—Portsmouth—Sidney—Urbana—Youngstown.
OREGON 232
Albany.
PENNSYLVANIA 232
Danville—Titusville.
VIRGINIA 232
Norfolk.
WEST VIRGINIA 232, 233
Martinsburg.
WISCONSIN 233
Black River Falls—Lacrosse.
GRAVITY SYSTEM AND PUMPING TO DISTRIBUTING RESERVOIRS 234-239
CALIFORNIA 234
San Francisco—Vallejo.
COLORADO 234, 235
Leadville.
ILLINOIS 235
Oregon.
IOWA 235
Muscatine.
MARYLAND 235, 236
Baltimore.
MASSACHUSETTS 236
Chelsea—Dorchester—Haverhill.
NEW JERSEY 236, 237
Burlington—Newark.
NEW YORK 237, 238
Canajoharie—Corning—Elmira—Port Byron.
PENNSYLVANIA 238
Bellefonte—Columbia—Lewistown.
VIRGINIA 238, 239
Staunton.
WASHINGTON 239
Olympia.
GRAVITY SYSTEM AND PUMPING TO STAND-PIPE 240
MINNESOTA 240
Stillwater.
PENNSYLVANIA 240
South Bethlehem.
TENNESSEE 240
Clarksville.
GRAVITY SYSTEM AND PUMPING DIRECT INTO DISTRIBUTING MAINS 241, 242
NEBRASKA 241
Omaha.
NEW YORK 241
Yonkers.
PENNSYLVANIA 242
Shamokin—Wilkesbarrre.
VERMONT 242
Saint Johnsbury.
PUMPING TO DISTRIBUTING RESERVOIR AND STAND-PIPE 243-245
ALABAMA 243
Mobile.
MASSACHUSETTS 243, 244
Brookline—Cambridge.

PUMPING TO DISTBIBUTING RESERVOIR AND STAND-PIPE—Continued. Page.
Ohio 244
West Cleveland—Zanesville.
Pennsylvania 244
Allentown.
Wisconsin 244, 245
Milwaukee.
PUMPING TO DISTRIBUTING RESERVOIR AND MAINS 246–254
Alabama 246
Birmingham.
Florida 246
Jacksonville.
Illinois 246, 247
Alton—Jacksonville—Morrison—Springfield.
Indiana 247, 248
New Carlisle—Peru.
Iowa 248
Anamosa—Lyon—Ottumwa.
Kentucky 249
Bowling Green.
Massachusetts 249, 250
Attleborough—Lawrence—Plymouth—West Newton—Woburn.
Michigan 250
Grand Rapids.
Missouri 251
Hannibal—Sedalia.
New Jersey 251
Elizabeth.
New York 251, 252
Buffalo—Rome.
Pennsylvania 252, 253
Bethlehem—Bloomsburg—Chambersburg—Media—Pottstown.
Tennessee 253, 254
Memphis.
Texas 254
San Antonio.
Wisconsin 254
Menomonee.
PUMPING TO STAND-PIPE AND DISTRIBUTING MAINS 255
Illinois 255
Wilmington.
Iowa 255
Clinton.
Texas 255
Houston.
GRAVITY SYSTEM AND PUMPING TO DISTRIBUTING RESERVOIR AND STAND-PIPE 256
District of Columbia 256
Washington.
GRAVITY SYSTEM AND PUMPING TO DISTRIBUTING RESERVOIR AND MAINS 257, 258
Missouri 257
Kansas City.
New Jersey 257
Lambertville.
New York 257, 258
Syracuse.
GRAVITY SYSTEM AND PUMPING TO STAND-PIPE AND DIRECT INTO DISTRIBUTING MAINS 259
Pennsylvania 259
Tioga.
PUMPING TO DISTRIBUTING RESERVOIR, STAND-PIPE, AND MAINS 260, 261
Massachusetts 260
New Bedford.
Pennsylvania 260, 261
Catasauqua—Erie.

LIST OF ILLUSTRATIONS.

	Page.
Croton dam	7
Croton aqueduct	8
Croton water-works—masonry dam for storage reservoir	9
Plan of dam for storage reservoir on middle branch of Croton river	10
Dam, bulkhead, and gateway	11
Various forms of Croton aqueduct at different places	12
Waste-weirs and ventilators built at various points on the aqueduct	12
Elevation and section of High bridge	13
Transverse section of High bridge as altered	14
Map of Lake Cochituate	17
Plan and section showing method of conveying water across Charles river	18
Longitudinal vertical section of lower gate-house at Chestnut Hill reservoir	20
Intermediate gate-house at Chestnut Hill reservoir	20
Influent gate-house at Chestnut Hill reservoir	21
Map of Brookline reservoir	21
Sudbury river conduit	25
Parker Hill distributing reservoir	28
Sections of Parker Hill distributing reservoir	29
Section of Parker Hill distributing reservoir	30
Map of the Cherry Hill reservoir	35
Section through Ludlow dam	35
Plan of Cherry valley dam	36
Roll-way and waste-gates, Cherry valley dam	37
New London water-works	39
Norwich water-works	42
Rutland water-works	45
Section of Burlington water-works	51
Sections of Burlington water-works	52
Pumping-engine of the Burlington water-works	53
Sandusky water-works pumping station	58
Sandusky water-works	59
Interior of filter-basin, stand-pipe in the distance	62
Pump station of Toledo water-works	63
Pumping-engine of the Detroit water-works	65
Compound pumping-engine of the Detroit water-works	66
Main pumping-works, Providence, Rhode Island	70
Providence water-works—Cornish pumping-engine No. 1	71
Reservoir at Providence, Rhode Island	72
Outlet-chamber of reservoir, Providence, Rhode Island	73
Hope Station	74
Sectional elevation through center of cylinders	75
Nagle engine	75
End view, showing opening for reducer	78
Front view of hub-casting	78
Longitudinal section through reducer	78
Dean pump	79
Pumping engines, Brooklyn, New York	86
Pumping-engine, Brooklyn, New York	87
Sections of reservoir at Brooklyn, New York	88
Sections of reservoir at Brooklyn, New York	89
Sections of reservoir at Brooklyn, New York	90
New Pittsburgh water-works building at Brilliant Station	91
Pumping-engine of the new Pittsburgh water-works building at Brilliant Station	92
Pumping-engine of the new Pittsburgh water-works building at Brilliant Station	93
Albany water-works—Section of tunnel and shaft	94

Prospect Hill reservoir embankments 96
Plan of main pumping works 102
Sketch of "No. 3 combination" pumping-engine 103
Sketch of "No. 4" pumping-engine 105
Sketch of "No. 6" pumping-engine 106
Vertical section of direct-action pumping-engine for the Cincinnati water-works 107
Plan of Eden Park reservoir 108
Section of main retaining wall, Garden of Eden reservoir 108
Duplex non-condensing Niles engine 109
Warden vertical compound engine 110
Engine-house, Cleveland, Ohio 112
Filter bed of the Lowell water-works 115
Worthington pumping-engine 116
Map of the city of Manchester 118
Manchester water-works 119
Dam of the Manchester water-works 119
Pumping-engine of the Manchester water-works 120
Distributing reservoir of the Manchester water-works 120
Distributing reservoir—Sections of effluent chamber 121
Pumping station, Bangor water-works 122
Bangor water-works—Section of gallery 123
Plan of Fairmount water-works 125
Map of the Philadelphia water-works 126
Fairmount pumping station 127
Fairmount reservoir 129
Corinthian avenue reservoir 130
Pumping-engine of the Schuylkill water-works 131
Sections of pumping-engine of the Philadelphia water-works 132
Plan of East Park reservoir 133
Plan of Schuylkill reservoir 134
Plan of Belmont reservoir 135
Plan of Delaware reservoir 136
Engine No. 2, Delaware works 136
Cramp engine, Frankford works 137
Frankford reservoir 138
Section of embankment at inlet 138
Details of gate-house, Frankford reservoir 139
Longitudinal section through stop-house 139
Plan of Chestnut Hill water-works 140
Pipe bridge, Roxborough works 140
West Philadelphia stand-pipe 142
Details of stand-pipe for Spring Garden works 143
Saint Louis water-works, plan and section 145
Pumping station of Saint Louis water-works 145
Pumping-engines of the Saint Louis water-works 146
Pumping-engines of the Saint Louis water-works 147
Plan of settling reservoirs 148
Cross-sections through walls of settling reservoirs 148
Saint Louis water-works, high-service pumping station 149
High-service pump 150
High-service engine No. 3 150
Reservoir at Compton Hill 151
Rochester water-works—Plan of the storage reservoir at Rush 154
Mount Hope reservoir 154
Cross-section of bank of distributing reservoir, Rochester 155
Cross-section of bank of storage reservoir, Rush 155
Plan showing manner of laying pipes under bank of distributing reservoir; also plans of straining-well and gate-house 156
Plan of fountain for distributing reservoir 157
Section showing a connection between the mains of the Domestic and Holly systems 158
Section showing the relative positions in the trench of the mains of the Domestic and Holly systems 158
Pumping-engine of the Rochester water-works 158
Plan of cast-iron stop-gate box 159
Plan of air-and-vacuum valve for conduit 159
Map of water-supply of Troy, New York 161
Sections of gate-house, Pawtucket reservoir 163
Pumping-engine of the Pawtucket water-works 164
Sections of gate-house, Pawtucket reservoir 166
Section of Pawtucket reservoir 167
Filter basin of Poughkeepsie water-works 168

LETTER OF TRANSMITTAL.

SCHOOL OF MINES, COLUMBIA COLLEGE,
NEW YORK, *June* 1, 1882.

Hon. CHAS. W. SEATON,
Superintendent Tenth Census.

SIR: I have the honor to forward to you the report of Mr. Walter G. Elliot on the water-supply of certain cities and towns of the United States. Under Gen. Francis A. Walker's direction the subject was taken up by the division of the census under my charge, and Mr. Elliot, of this city, was appointed to visit a large number of the principal cities and towns of the country, and to ascertain by personal examinations and inquiries every thing of public interest connected with the water-supply of such towns. His report therefore contains a large amount of valuable information which can not be found elsewhere.

The statistics published in connection with Mr. Elliot's report of towns not mentioned by him were collected by correspondence directly from my office, this work having principally been accomplished by Mr. Fred. N. Owen, of New York, a graduate of the School of Mines, Columbia College, to whom I was indebted for much valuable assistance in the prosecution of the census work intrusted to me by General Walker.

I have the honor to be, very respectfully, your obedient servant,

W. P. TROWBRIDGE,
Chief Special Agent, Tenth Census.

INTRODUCTION.

In a consideration of the water-works of the country and a description thereof, it has been found convenient to group them according to their systems of supply, rather than according either to the population of the cities, or to the magnitude or peculiarities of these systems. For this purpose, therefore, the systems have been classed as follows:

1. Gravity supply;
2. Direct pumping;
3. Pumping to stand-pipe;
4. Pumping through stand-pipe, the surplus above consumption passing to reservoirs;
5. Pumping through stand-pipe to reservoirs;
6. Pumping direct to reservoirs;
7. Pumping by water-power.
8. Combinations.

Nos. 1 and 2 may be considered pure types, and the rest merely modifications of these types; but the distinctions have been used for convenience in reference.

A pure type of each system will be described in the course of this report, and, as a rule, the largest and most complicated of each will be selected as embodying all peculiarities contained in the smaller and simpler ones.

Thus, of the eight systems, we may consider New York and Boston as types of No. 1; Burlington (Iowa) and Indianapolis as types of No. 2; Chicago, Toledo, and Sandusky as types of No. 3; Providence and Memphis as types of No. 4; Nashville as a type of No. 5; Lowell, Pittsburgh, and Cincinnati as types of No. 6; Manchester (New Hampshire) and Bangor as types of No. 7; and Philadelphia as a type of No. 8.

It has been the endeavor, so far as possible, to obtain details of cost of the pure types, in order that a comparison of the original and maintenance costs may be made. Wherever possible to obtain them, photographs of pumping-engines, pump-houses, stand-pipes, drawings, etc., have been added to aid description and to exhibit peculiarities.

Items of interest—facts obtained by observation from civil and mechanical engineers and superintendents of works—are given when they appear trustworthy, and details not obtainable by personal examination, or by personal application to the engineers, have been freely taken from printed reports.

In the different pumping-stations there is an endless variety of engines, with all grades of duty from 15,000,000 to 120,000,000 foot-pounds. Cornish engines, of which there are a considerable number, are usually of a capacity of from 3,000,000 to 10,000,000 gallons per 24 hours; and while, as a general rule, they show high duties, they are invariably very expensive in first cost, and are so cumbersome that it becomes a long and difficult operation to execute repairs. They have been erected less frequently each year.

WATER-PIPES.

With regard to the use of different kinds of water-pipe much can be said *pro* and *con;* but wrought-iron and cement pipes are being gradually replaced by cast iron in towns where they have been used for any great length of time.

It seems to be the verdict of engineers and water-works authorities generally that cast-iron pipes are strongest and most durable, most expensive in first cost, most liable to incrustation save when coated with tar, as in modern practice, most easily laid, tapped, and manipulated, and require least excavation. As to their durability, those which were first used in the country were laid with no coating on the inside, exposing a rough cast surface to the action of water flowing through them for from 20 to 30 years. The result was a rapid formation of tubercles, and consequent reduction of the effective diameter. This has taken place in many instances to such an extent that, in cases which I have seen, a 16-inch pipe has been reduced to 12 inches, and one of the latter diameter to 6 inches. They had been buried ten years. A 24-inch main, which had been coated before laying, in one of the thoroughfares of New York, on being removed in sections after 10 years' use, had this formation to a thickness of 1 inch.

Undoubtedly cases of much greater incrustation have been encountered in different cities, but the above, coming under my observation, will serve as illustrations. On the other hand, cement-lined pipes are cheaper in first cost, the joints are easily made, and their diameter remains undiminished indefinitely. As originally laid, such pipe consisted of a thin shell of sheet iron lined with 1 inch of Portland cement, and jointed together at the ends in a variety of ways. It was afterward laid in the trench and surrounded with cement or concrete. This class rusted badly, and soon wore out. An improvement upon it was an exterior coating similar to the interior. This lasts much longer, but is fragile. Later improvements promise better results. Bored wooden logs are now little used, but have done good service. They are still laid to good purpose in Detroit (*q. v.*), and are the cheapest yet designed. A very common but unscientific practice is the placing of iron gates in cement mains. Incrustation soon diminishes the effective capacity of the pipe to that of the incrusted gates.

FILTERING BASINS.

Filtering basins are those in which the water is allowed to flow freely upon beds such as below described, and, after downward filtration, is collected in a well or chamber at one end. There are but few of these in the country. Where used they are of uniform construction, differing only in shape to conform to peculiarities of topography.

Generally speaking, the water is allowed to percolate through about 4 or 4½ feet of sand and gravel in layers, the lowest being about 12 inches of 4-inch stones, overlaid with 8 inches of smaller stones, and that in turn by from 1 to 2 feet of gravel, the top stratum being from 1 to 2 feet of fine sand. Where most effective these basins are supplied by gravity from some stream, on the banks and below the level of which they are situated. The amount of water filtered in a given time varies greatly with the head of water on their surface, length of time in use, length of time since cleaning, character of organic or mineral matter in suspension, etc. This matter is therefore given as minutely as possible in the report upon each city where filters are in use. They are expensive in construction, and therefore are seldom built of sufficient capacity to be of use for more than a few years at a time, and are a constant source of trouble. The best types may be seen at Burlington, Iowa, and Bangor, Maine. Quite a number have been built and after a short use abandoned, as seen in Toledo, Ohio; Providence, Rhode Island; Columbus, Ohio, and other cities. Lowell, Massachusetts, has a filter of peculiar construction, but of only partial efficiency, owing to small size and rapid fouling.

The greatest difficulty is experienced in the filtration of water bearing much clay in suspension, the operation being so troublesome and expensive as to warrant in many cases the abandonment of such a source of supply. The trouble arises from the fact that it requires much time to settle if first led into subsiding basins. After a brief period it clogs up the interstices in the sand of the filtration basin, or forms an impervious clay coating, all action thereupon ceasing. In Toledo at times the diminution in the quantity of water filtered was so rapid as to be perceptible each day. Aquatic plants seldom prove troublesome in this respect, though always more or less so at the screens of inlet-chambers.

Impounded waters are almost universally troublesome at certain periods, owing to the so-called "fishy" odor and peculiar taste, which seems in no two cases to be ascribed to the same cause. As a rule, it does not appear noticeable in the bodies of water themselves, but develops itself after passage through the pipes on being drawn from the faucets. Trouble from the aquatic plants which appear at certain seasons of the year is usually prevented by changing the depth at which the water is drawn. One of the simplest methods of accomplishing this is by means of the apparatus described under Norwich, Connecticut.

Of infiltration galleries, where water percolating through the surrounding soil is collected into a gallery or tunnel and thence flows to the collecting well at one end, the best type is found at Columbus, Ohio (*q. v.*), where the supply is obtained from a sand and clay soil. Another instance is at Dubuque, Iowa, where water is supplied from crevices in the limestone. Water thus obtained is generally of remarkable purity, although in the case of Dubuque it is hard by reason of the carbonate of lime dissolved out of the neighboring rock.

COMPARISON OF SYSTEMS.

A careful examination of the report will show that the gravity system is most in vogue in the East, where the country is more mountainous and the settlement of earlier date, and the Holly or the stand-pipe system in the West, where the country is level. The gravity system is, as a general rule, operated with less expense than any other, save the Holly system run by water-power; it is usually more expensive in first cost, thereby necessitating a greater amount of annual interest. The increase in cost is due to extra length of conduit required by the remoteness of the source of supply, and in most cases to the cost of a distributing reservoir, for the same reason. There are but few cases in which such a reservoir is dispensed with in a gravity system. The dam is also an expensive necessity. Where water-power is available, the system of direct pumping with a Holly engine seems to be the most economical in every way. Illustrations of this may be cited in the case of Manchester, New Hampshire, and Bangor, Maine, leaving out of consideration the cost of a filtering gallery in the latter instance.

PURITY OF WATERS.

The purest and best drinking waters are those derived from springs in granite, trap-rock, and sandstone formations. Next in order of purity are the impounded waters of small streams, uncontaminated by passage through manufacturing or cultivated districts. These, however, usually contain more organic impurity than the former. Wells properly located in sandy districts furnish a supply free from mineral impurity, and almost wholly without organic contamination.

The supplies derived from rivers, of which system there are probably the largest number of examples, vary from exceeding purity to water almost unfit to drink, as in some cities where the rivers are polluted with sewage, and often are of very bad odor. In such cases it is not unusual for visitors to be affected as soon as they drink of the water. In the case of the Mississippi and Ohio rivers, the mechanical impurities are in such amount as to render the water unfit for use without settling or filtration.

ILLUSTRATIONS.

Many of the illustrations were made from photographs taken upon the spot, and from which the photo-engraved plates were executed.

WATER-SUPPLY OF CITIES.

1.—GRAVITY SUPPLY.

NEW YORK, N. Y.

The city of New York contains 1,206,299 inhabitants, and is located at the confluence of the Hudson and East rivers, the latter being a tidal estuary connecting New York bay with Long Island sound. The main portion of the city is limited on the north by a small tidal stream known as Harlem river, and connecting the East and Hudson rivers at points respectively 7 and 13 miles from the southern extremity, a point known as the Battery.

Topographically, from Canal street (1½ mile from the Battery) to the lower end, the city slopes each way from a central ridge (Broadway) to the rivers. Canal street, at right angles to Broadway, is in a hollow at nearly tide-level. Above this point to One hundred and twenty-fifth street, 6½ miles, the ground gradually rises to a total height of from 106 to 150 feet above tide-level. Above this the topography is exceedingly irregular, varying from tide-level to 200 feet elevation.

Geologically but two classes of material seem to underlie the city—gneiss rock in most places, and alluvial deposits or sand in the remaining parts.

Water from the Croton system of lakes and ponds was first introduced into the city in 1842. Ineffectual attempts had been made a number of times before to supply the city from wells, ponds, and small creeks within the city. In each case the water had proved insufficient in quantity and poor in quality.

The system in use is a gravity supply derived from a series of small lakes and brooks in Putnam and Westchester counties, at the confluence of which, known as the Croton river, a dam has been constructed, from which a brick and masonry conduit conveys the water about 40 miles into the city. At the crossing of the Harlem river a bridge, known as High bridge, of masonry, with fifteen arches, 50 and 80 feet span, conveys the water over the river through three pipes, two of 36 inches and one of 7 feet 6½ inches diameter. At the southern end of the bridge a set of pumping machinery draws water from the conduit and forces it into a high-service reservoir of small dimensions for the supply of an elevated district about Fort Washington and Washington Heights. From here the masonry conduit continues to Manhattan valley. It crosses the latter along Tenth avenue by means of iron pipes, the greatest depression of which is 105 feet below aqueduct line. There are two 36-inch pipes, one 48-inch pipe, and one 60-inch pipe. They are connected with the aqueduct at each end through masonry gate-chambers.

From about One hundred and seventeenth street to Ninety-second street, iron mains convey the water to gate-houses at the latter point near Ninth avenue. From the gate-houses the water flows through part of the original aqueduct, and also through pipes (details of which could not be accurately ascertained) eastward into the receiving reservoirs in Central park between Fifth and Seventh avenues.

There are two of the latter, one built in 1840 and the other in 1862. The former is now almost useless. From here the water flows through Fifth avenue to a small distributing reservoir of masonry at Forty-second street to Fortieth street; this reservoir is about to be removed on account of its small capacity, it holding less than one-quarter of a day's supply. The Central Park receiving basin will then become the distributing reservoir of the system.

The Croton river has its origin in Putnam county, New York, and is fed by small brooks and lakes on its course to the Hudson river, into which it empties just above Sing Sing, on the east bank of the river, 40 miles above New York. The geological structure of the country through which it flows is of gneiss, mica, slate, and sandstone formations, with a little limestone.

The entire drainage area of the Croton river is calculated from surveys of 1857–'58 at 338.82 square miles, and there are fifteen main ponds and lakes in which the water is gathered or stored; most of them, having had the

original proprietors' names attached, are now designated by letters of the alphabet. The following list gives particulars concerning them:

Reservoir.	Area.	Capacity.	Drainage area.	DAM.		Length of reservoir.	Distance from Croton dam.	Elevation.
				Extreme depth.	Extreme length.			
	Acres.	*Gallons.*	*Sq. miles.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*	*Feet.*
A	485.00	5,211,015,625	20.45	64	1,500	12,300	9.50	390
B	192.00	1,701,835,337	15.20	55	1,700	6,000	12.75	500
C	730.00	6,589,101,562	13.71	43	1,700	16,600	14.30	550
D	1,008.00	9,033,632,812	41.95	48	770	21,000	20.25	500
E	303.00	3,369,206,857	20.37	64	700	7,500	23.75	600
F	600.75	6,120,335,937	12.51	21	1,560	10,600	15.50	560
G	452.59	4,861,035,156	20.90	73	541	12,200	18.70	375
H	384.67	2,490,062,500	75.46	40	545	14,748	19.39	375
I	449.00	4,205,820,654	70.52	62	331	12,745	20.45	415
J	191.38	2,314,074,703	11.92	69	1,311	11,616	28.71	500
K	512.74	5,671,449,219	78.90	72	904	14,809	15.21	275
L	262.75	2,328,217,733	26.86	74	757	13,120	16.54	295
M	492.25	4,392,131,445	23.34	72	925	12,300	13.83	316
N	197.00	1,676,049,171	30.96	60	686	8,650	7.71	250
O	239.47	2,182,337,109	17.32	90	1,170	7,629	9.97	305

Of the above list, only two are artificial, that at Boyd's Corners—reservoir E—and that at Middle branch of Croton river—reservoir G; but it is intended eventually to dam all of the outlets from the natural lakes and ponds and convert them into storage reservoirs of greater capacity. The dam at E (Boyd's Corners) is one of the finest and best-constructed masonry dams in this country.

These two dams, built at a cost of $1,510,000, will be described separately. The minimum flow of the Croton river is stated at 27,000,000 gallons per day, and the daily average in dry years varies from 300,000,000 to 367,000,000 gallons. Of this amount, at present only about 100,000,000 gallons (95,000,000 in 1880) passes through the aqueduct for consumption in the city.

The Croton dam, having been first constructed, may appropriately be described here. The chief engineer of the work was John B. Jervis, C. E., with Horatio Allen, C. E., as first assistant.

The dam, which backs up the water for several miles, forming Croton lake with an area of 400 acres, is 434 feet long, 284 feet of which is in masonry and the remainder of earth embankment.

The greater part of the structure rests upon a stratum of alluvial soil containing bowlders, the left bank, however, being granite and gneiss rock.

The piers C and D, of timber, with walls connected by ties, were first constructed and filled in with stone. The top was planked, and upon it the two smaller wooden piers F and G were built and filled in as before. Pier F was planked on top.

The space E was then filled in with concrete, and the tops of F and G were connected by ties of timber. Another pier, H, was then constructed in front of D, the top in front of it being filled in with concrete.

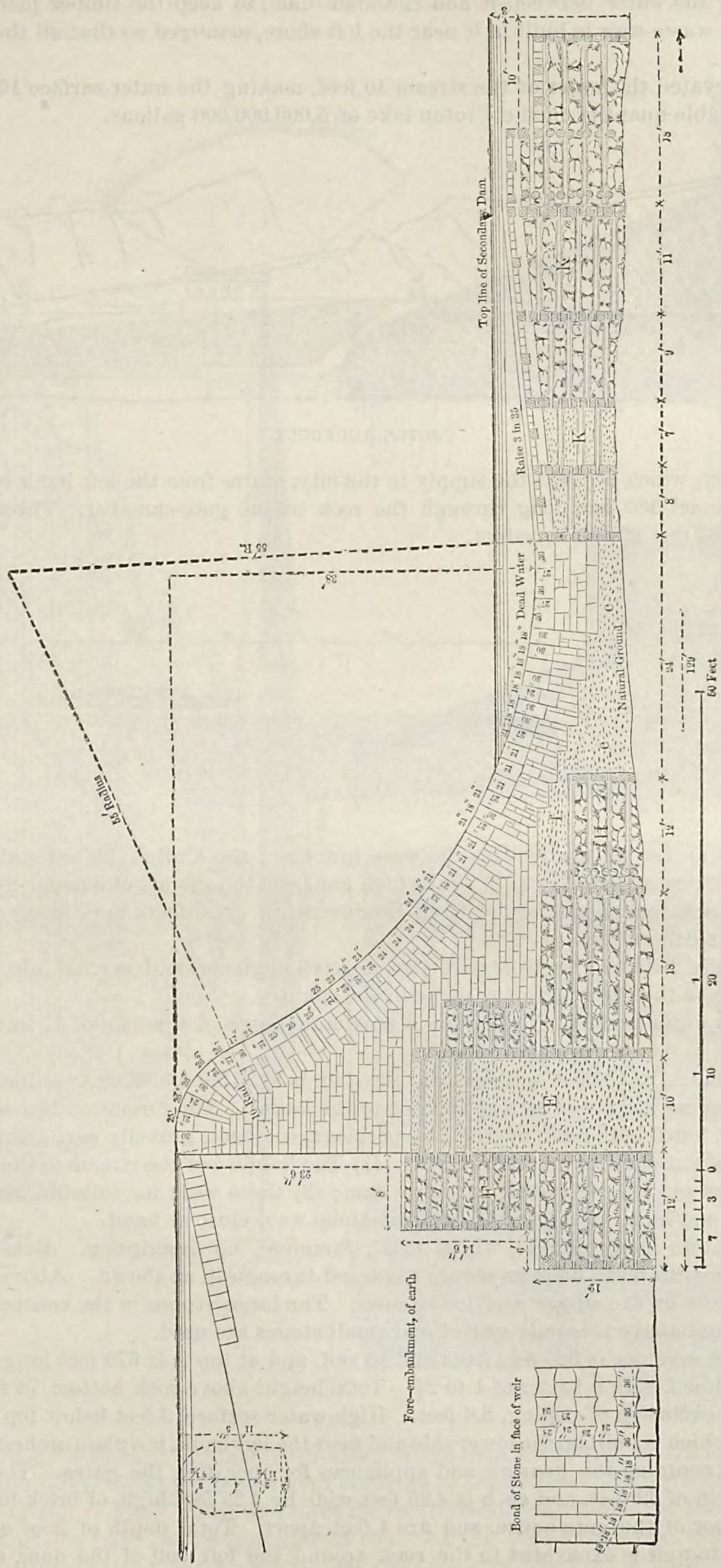
The piers K, K, in four compartments, were put down, two being filled with concrete and two with stone. They were of 12- by 12-inch timber, and the top was covered with a planking laid upon a slope rising 3 feet in 35 feet, as shown in the cut. The front of this "apron" is protected by another pier of timber filled with stone and faced with heavy planking.

Upon the foundations E, D, G, and H, already described, the masonry of the dam was constructed. It was set in hydraulic cement, the main body being laid in horizontal layers, and the facing of finely cut granite blocks bonded together being laid in a reversed curve. At the crest it is convex, and has a radius of 10 feet. This curve at a few feet below the crest tangentially joins the reverse or concave curve built to a radius of 55 feet.

The general objects of this arrangement and of the apron, the details of which are given in the cut, are to break the fall, and, as nearly as possible, to conform to the curve of the overfalling water. The face blocks are from 17 to 24 inches wide and 24 inches deep.

The upstream side of the dam is filled in against the piers and masonry with earth, forming a gentle slope up stream. For a distance of 20 feet from the crest this embankment is paved with granite blocks, laid dry to prevent damage by wave-wash. From the right end of the overfall to the right bank the dam is of earth; details of the construction could not be obtained.

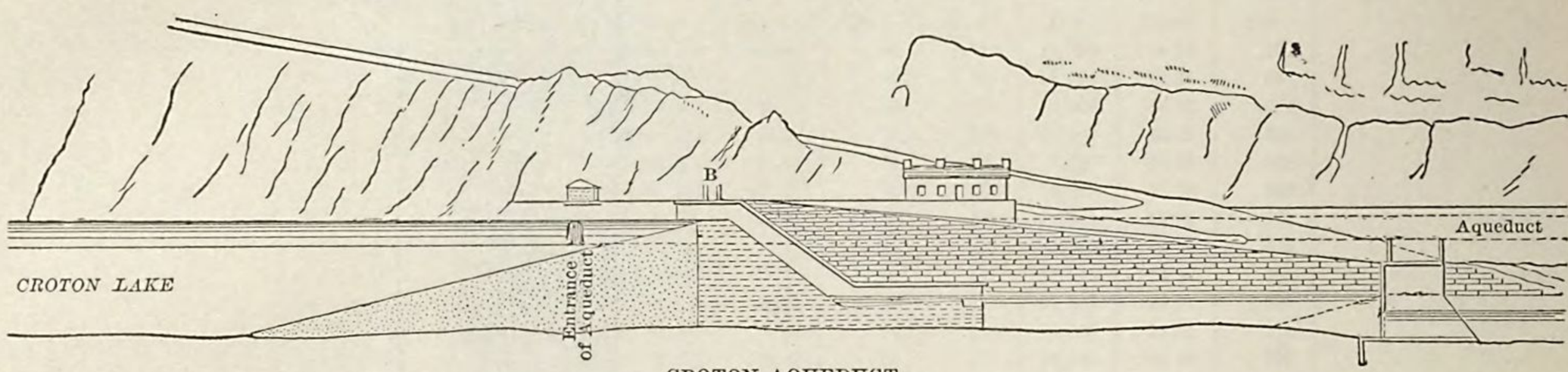
Near the left end of the dam, 90 feet from the river-bank, a waste-culvert is built through the masonry 22 feet below the crest, and closed by two sets of gates operated from within a gate-house 14 feet square, situated on the crest and reached from the river-bank by a foot-bridge.


Top line of Secondary Dam
Raise 3 in 35
Dead Water
Natural Ground
Fore-embankment, of earth
Bond of Stone in face of weir
60 Feet

CROTON DAM.

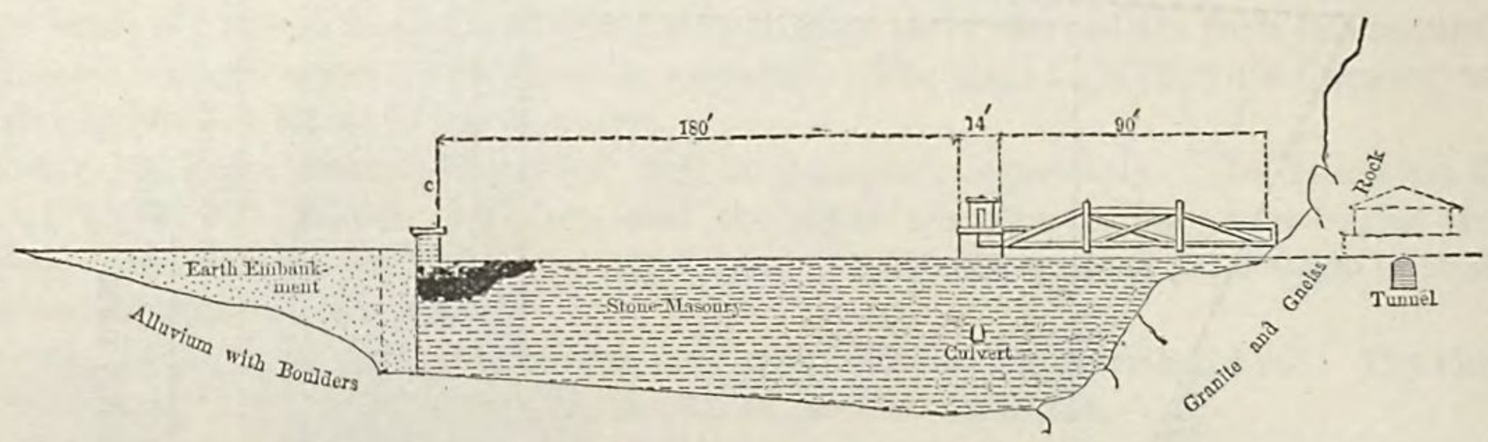
A secondary dam is built 300 feet down stream from the main one. It is of timber filled with stone, and is intended, by backing the water between it and the main dam, to keep the timber piers K and L of the latter always submerged. A waste-weir is built in it near the left shore, arranged so that all the water above it may be drawn down.

The Croton dam elevated the water of the stream 40 feet, making the water-surface 166 feet above mean tide, and containing an available quantity in the Croton lake of 5,000,000,000 gallons.



CROTON AQUEDUCT.

The Croton aqueduct, which conveys the supply to the city, starts from the left bank of the river immediately above the dam, in a tunnel 180 feet long through the rock to the gate-chamber. Throughout this length it is somewhat larger than the rest of the aqueduct.



The large reservoir at Boyd's Corners on the west branch of the Croton, 23 miles above the Croton dam, is formed by a masonry dam constructed in 1870, and which has been the subject of a paper by Mr. James J. R. Croes, civil engineer, before the American Society of Civil Engineers (*a*). The facts here given concerning it have been almost exclusively derived therefrom.

The dam, as originally designed by George S. Greene, civil engineer, and carried into execution by Mr. Croes as chief engineer, is one of the finest masonry dams in the country.

The reservoir has a water-surface of 279 acres, a maximum depth at the dam of 57 feet, and an average depth of 30 feet.

The capacity is about 2,729,430,000 gallons, and the dam is situated between two lines of hills (which at this point closely approach each other), and at right angles to the valley. The formation beneath the stream here was gneiss, and fine-grained, hard, blue rock, overlaid by pervious, compact, gravelly earth and drift.

The dam was built of masonry for several reasons: (1) The liability of the stream to sudden and heavy freshets, which would have destroyed a half-finished earthern dam; (2) there were no suitable materials for puddling at hand; (3) good quality and large quantities of building-stone were close at hand.

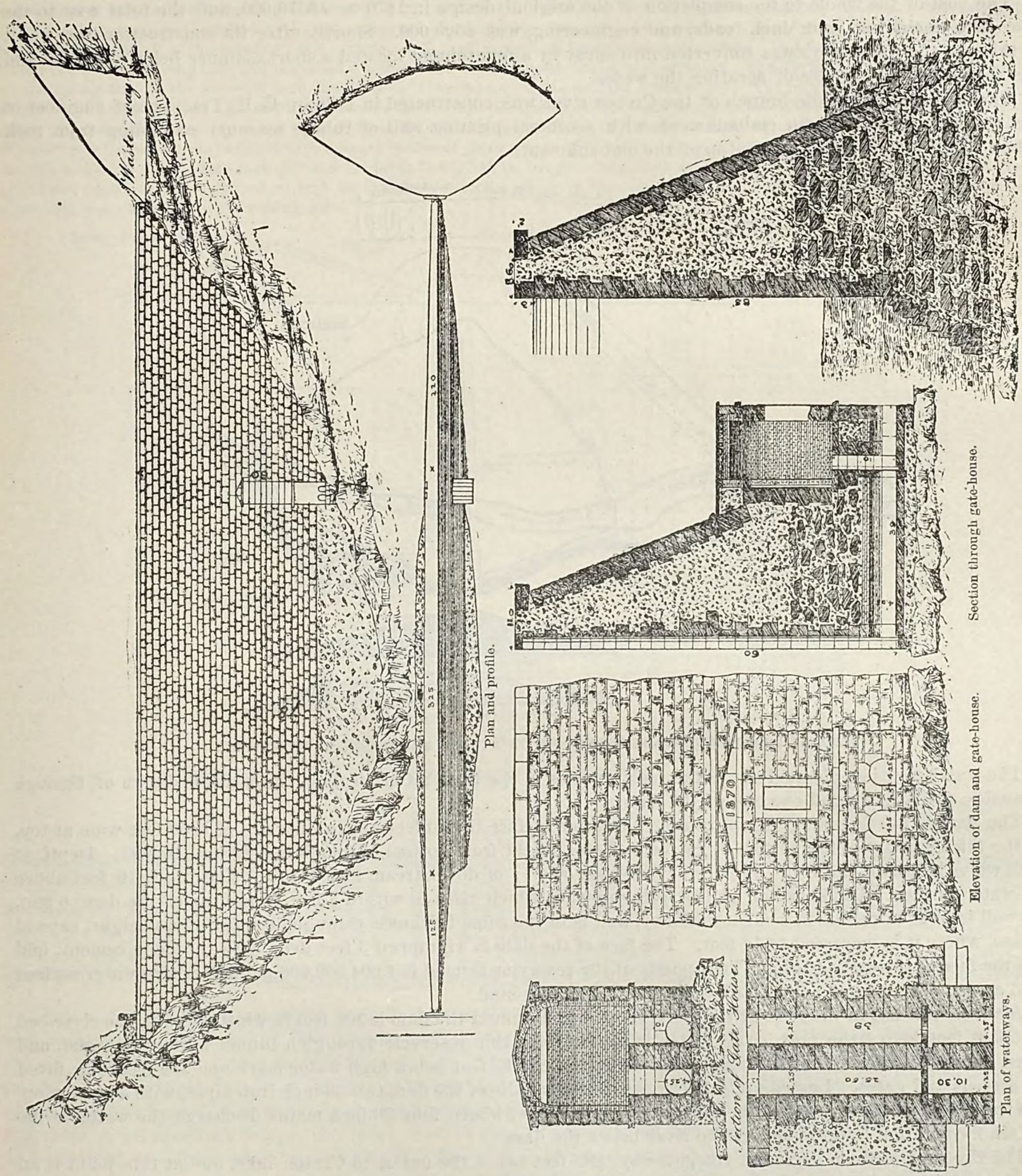
The cut (page 9) shows many details, which need, therefore, no description. Below the stream-level the foundation is of concrete, with large unhewn stones scattered through it, as shown. Above this level hewn blocks in courses face the concrete on the upper and lower sides. The large stones in the concrete center extend for 15 feet above the stream, and above this only gravel and small stones are used.

The lower line of the masonry is 325 feet from end to end, and at top it is 670 feet long. The upstream face is vertical, the other is inclined, with a batter of 1 to 2½. Total height above rock bottom, 78 feet; width or thickness at base, 57 feet; at top, exclusive of coping, 8.6 feet. High-water surface, 3 feet below top of dam.

The gate-chamber, which is built on the lower side and near the left bank, is a plain arched chamber of brick-work, about 22 by 18 feet, and contains the gearing and appliances for operating the gates. There are two water-ways through the dam, a length of 39 feet, and each is 4.25 feet wide by 4.25 feet high, of brick in cement. The bottoms are 10 feet below the floor of the gate-house, and are 4 feet apart. Total depth of floor of water-ways below top of dam, 60 feet. A waste-weir is excavated in the rock around the left end of the dam, and the overfall at that end was arranged in three sections, the one at the extreme end cut in the rock, being 30 feet long at flow-line, the

a Published by the society in February, 1875.

second 9 inches higher over the masonry and 100 feet long, and the third 1½ foot above flow-line and 70 feet long. The rock at the base of the face-wall was cut in steps for 220 feet. Grooves for stop-plank were built in the upstream face of the dam over the water-ways.



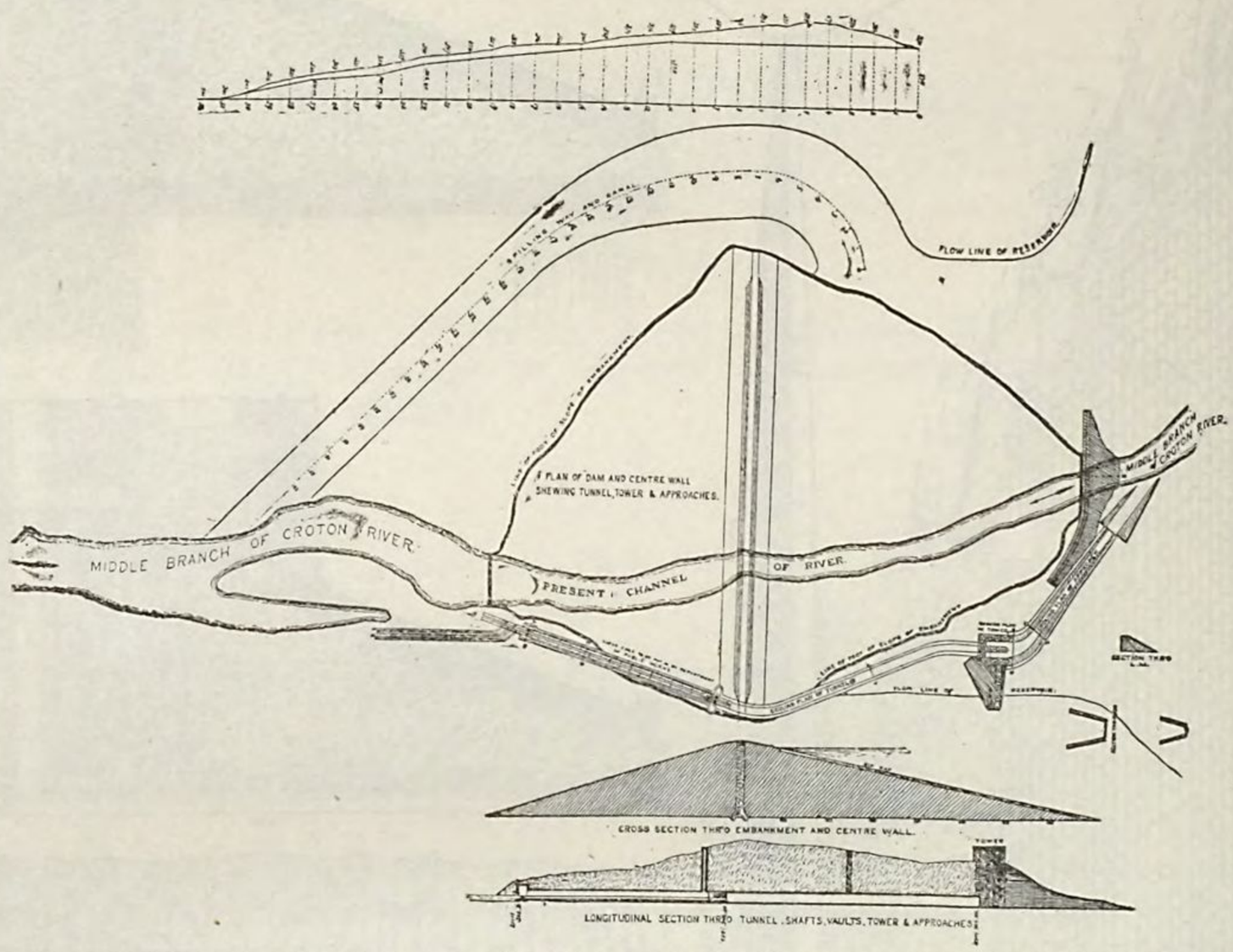
CROTON WATER WORKS—MASONRY DAM FOR STORAGE RESERVOIR.

An earth embankment was built against both sides of the dam for 10 feet above stream-level. A change in the management of the Croton aqueduct department occurred in 1870, when the construction was nearly completed. The new officers altered the original plans and built an earth embankment against the upstream or vertical face of the dam, with a slope of 5 to 2, and 20 feet wide at top. At the toe of the slope, in front of the water-ways, a masonry tower was built above the water-surface. Grooves for stop-plank were built in it, and from its foot two 36-inch iron pipes were laid through the embankment and water-ways, and carried several hundred feet below the dam. The rock excavation at the end of the same, for the waste-weir, was increased to 100 feet in width.

The result of these changes was to change the dam from one amply strong for any water-pressure, to a retaining-wall for a saturated earth embankment, so near the limit of stability as to be almost if not quite unsafe, the earth being more or less pervious, and no puddling having been used.

The cost of the whole to the completion of the original design in 1870 was $370,000, and the total cost to the same date, including land, dam, roads, and engineering, was $590,000. Shortly after its construction the water led through the water-ways was converted into spray by a fountain-jet located a short distance below the dam, and constructed for the purpose of aerating the water.

The dam on the Middle branch of the Croton river was constructed in 1878 by E. H. Tracy, chief engineer of construction. It is an earth embankment, with a central priming-wall of rubble masonry extending from rock bottom to within a few feet of the top of the embankment.



PLAN OF DAM FOR STORAGE RESERVOIR ON MIDDLE BRANCH OF CROTON RIVER.

The waste-weir is a channel cut in the rock, and, as in the Boyd's Corner dam, the water is drawn off through a tunnel in the rock around one end of the dam.

The dam is 740 feet long at top, raising the water-surface to 370 feet above datum. It is 50 feet wide at top, and the thickest part of the bottom is 380 feet. Total height from bottom of foundation of wall, 91 feet. Depth at which water is drawn, 63 feet. Slope of water-face, 5 to 1; of downstream face, 3 to 1. The top is 10 feet above high-water surface. Thickness of central priming-wall, which rises to within 3 feet of the top of the dam, 8 feet. This wall is built of rubble in cement masonry, and is of the same thickness throughout most of its height, save at its base, where it is increased to 16 feet. The face of the dam is riprapped 3 feet deep with rubble in cement, laid upon the face of the earth bank. The capacity of the reservoir formed is 4,004,000,000 gallons, with a water-surface of 433 acres. The ground submerged was entirely meadow-land.

A waste-weir cut in the rock at the westerly end and around the dam is 100 feet in width, joining the river-bed about 320 feet below the foot. The water is drawn from this reservoir through a tunnel around one end, and started above the inner toe of the dam, as shown in the cut, 63 feet below high-water mark and 285 feet long, fitted with screens and gates. Immediately after passing the middle of the dam two 30-inch iron pipes, with 30-inch stop-gates, replace it and convey it to the toe of the lower slope, where four 20-inch mains discharge the water in the fountain for aeration into the bed of the river below the dam.

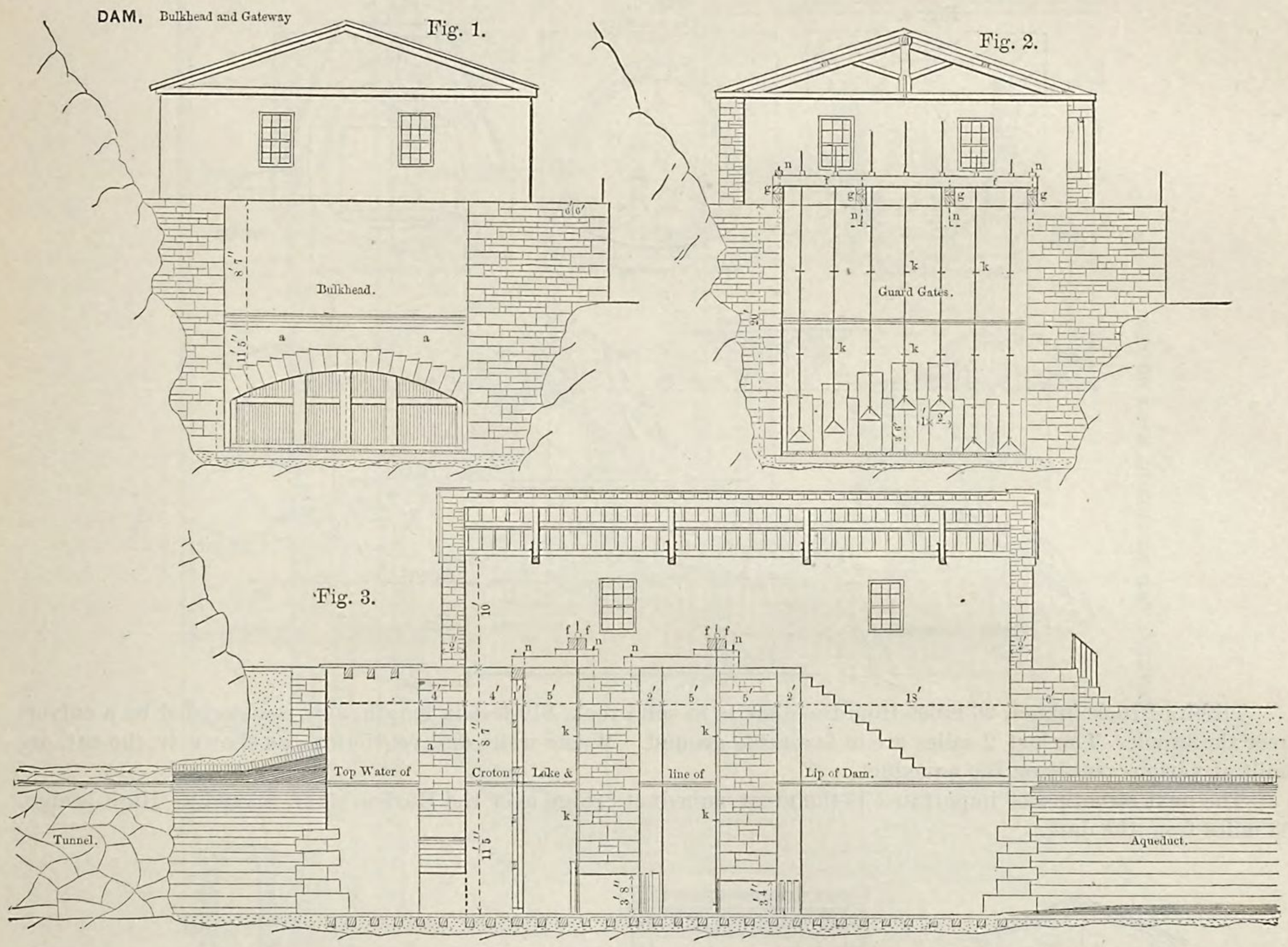
The Croton aqueduct begins at the gateway, 180 feet below the outlet to Croton lake, and at this point is an arched conduit of brick in cement. Details of the gateway are shown in the cut. At this gateway the water passes through an arch in the bulkhead, *a a*, the screens of brass netting, the guard-gates, and, lastly, through the regulating gates into the aqueduct. The aqueduct at the gateway is enlarged in width as shown, and is again diminished below the gates. The guard-gates are of cast iron in iron frames, and the regulating gates are of gun-metal. The following description is from the *Report of the Department of Public Works*, June 30, 1878:

The bottom is an inverted arch, the chord or span line is 6 feet 9 inches, and the versed sine 9 inches.

The masonry of the side walls rises 4 feet above the spring line of the inverted arch, with a bevel of 1 inch to a foot rise, or 4 inches on each side, which brings the width of the top of the side walls 7 feet and 5 inches, forming the abutments of the roofing-arch, which is

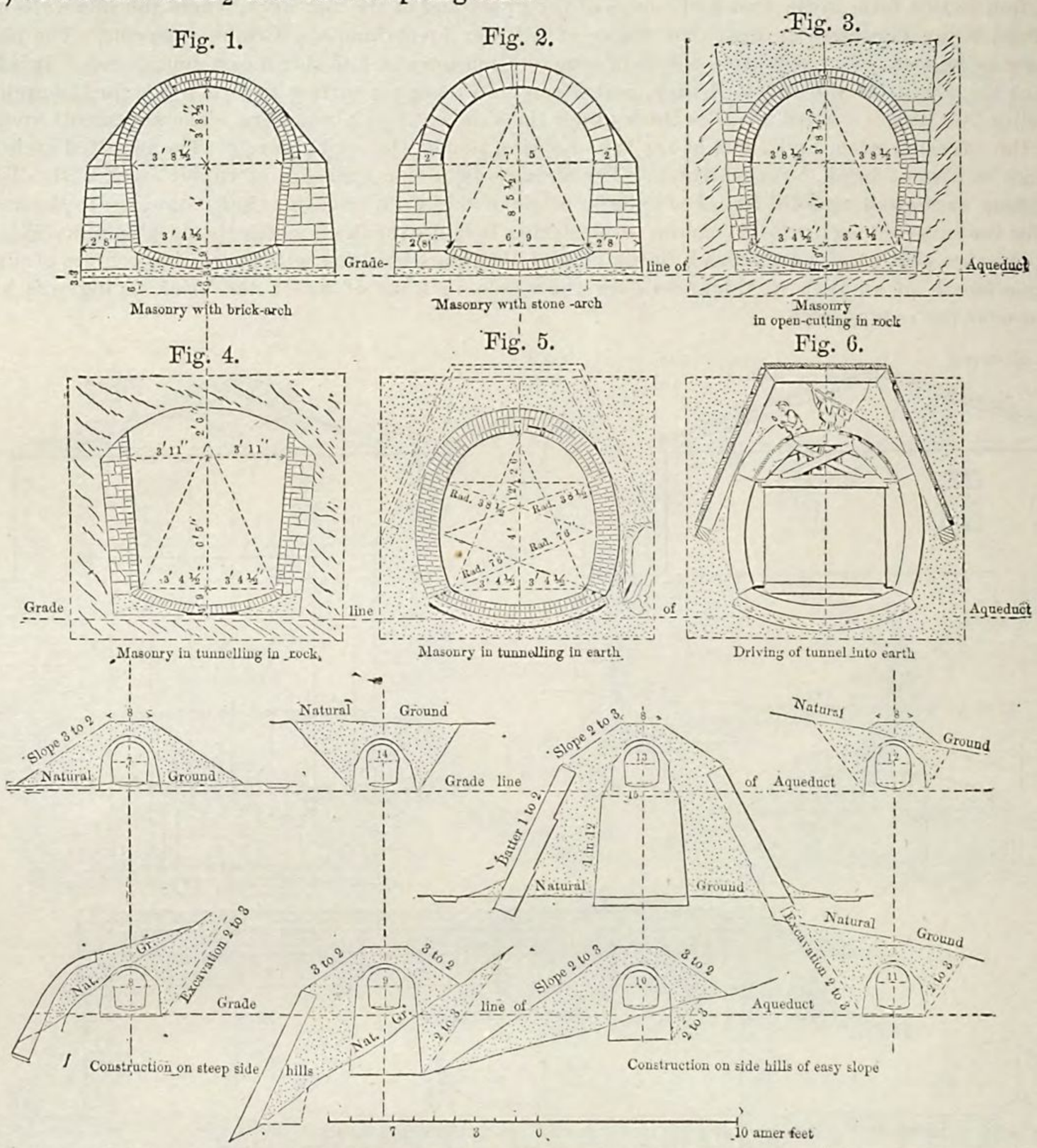
a semi-circle, having a radius of 3 feet 8½ inches, or a chord line of 7 feet 5 inches. It will therefore be perceived the greatest interior width is 7 feet 5 inches, and the greatest height 8 feet 5½ inches. The area of the interior is 53.34 square feet. In rock tunnels the roofing-arch is generally dispensed with, but the bottom and sides are formed with masonry similar to the above described.

There is an exception to this form in the first 4.949 miles of the upper end of the aqueduct, where the side walls have an extra height on account of the bottom being depressed to draw the water at a lower level from the Croton reservoir. The plan, dimensions, and character of masonry are as follows: In excavation a bed of concrete masonry is laid down as a foundation. It is laid level across the bottom 3 inches thick at the center of the inverted arch, and covered on its upper surface to form a bed for the arch, which brings it 12 inches thick at the spring line, and is carried 3 inches thick under the side walls or abutments. The abutments are 2 feet 8 inches thick at the spring line of the inverted arch, and 2 feet at the top or spring line of the roofing-arch. The inverted arch is of brick, 4 inches thick. The roofing-arch is also of brick, 8 inches thick. The abutments or side walls are of rubble-stone with a brick facing 4 inches thick. Spandrels of stone are caried up solid from the exterior angle of side wall, on a line that is tangent to the arch. Where the bed of concrete is formed for the inverted arch a heavy course of plastering is laid over it, on which the arch is laid. When the stone wall of the side walls was up, the face that received the brick lining had its irregularities filled with successive courses of plastering, and finally a uniform course of one-fourth of an inch in thickness over the whole, in front of which the brick facing was laid up. A course of plastering was also put over the roofing-arch.



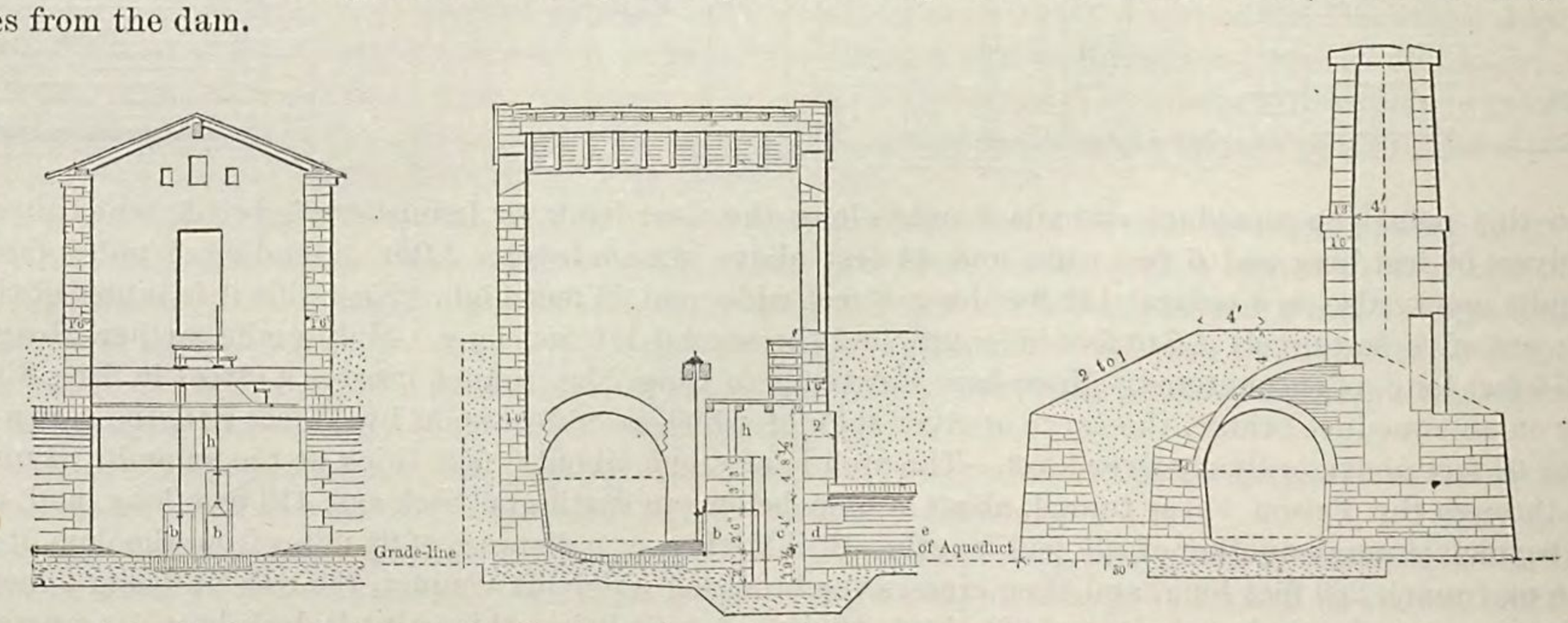
Below this point the aqueduct extends 1 mile along the river-bank to Lounsberry's brook, which it crosses with a culvert 66 feet long and 6 feet wide, and 44 feet above stream-level. After extending 5 miles farther it crosses India creek, also on a culvert 142 feet long, 8 feet wide, and 58 feet high. Near this it is tunneled through two hills; one of these tunnels is 740 feet in length, and the second 116 feet long. Half a mile farther, Hoag's Hill tunnel, 276 feet long, is encountered. From here it extends to Sing Sing tunnel, crosses a street in Sing Sing and Kill river on an aqueduct bridge, the large or river span of which is 88 feet span by 33 feet rise, the crown of the arch being 62 feet above ordinary river-level. The arch is of stone, about 3 feet thick at the summit. From here it passes through the Prison Farm tunnel, about a mile below, an earth and rock cut 416 feet long, and, a short distance beyond, through another of 375 feet length. Still farther, at a distance of 9½ miles from the dam, it passes Hale's Brook tunnel, 260 feet long, and then crosses the brook on a culvert viaduct, the culvert being 6 feet wide, 131 feet long, and 49 feet below the top of the back-filling. A mile below this point Rider's brook is crossed by a culvert 100 feet long, 6 feet wide, and 34 feet high. Near by it crosses a highway by a bridge similar to that over Kill river, and at 11½ miles from the dam passes through Austin Farm tunnel, 186 feet long. It crosses Mill river 13 miles from the dam, on an aqueduct bridge 25 feet wide and 172 feet long. In the next 2 miles are 5 culverts, and a tunnel 246 feet long through rock, known as the White Plains tunnel. Another, at Dobbs Ferry, is 262 feet long, driven through earth. The cut on page 12 shows the various forms at different places. From this point

to below Yonkers there are a number of culverts, and at the latter place is a tunnel known as the Saw-Mill River tunnel, through earth, and 684 feet long. Beyond this is the Saw-Mill River bridge, a stone structure in 2 arches, each 25 feet span, and a rise of 12½ feet above spring line.



Tibbits Brook tunnel, 26 miles from the dam, is in solid rock, 810 feet in length, and is succeeded by a culvert over the brook. The last 2 miles are in favorable ground. Waste-weirs and ventilators, as shown in the cut, are built at various points on the aqueduct.

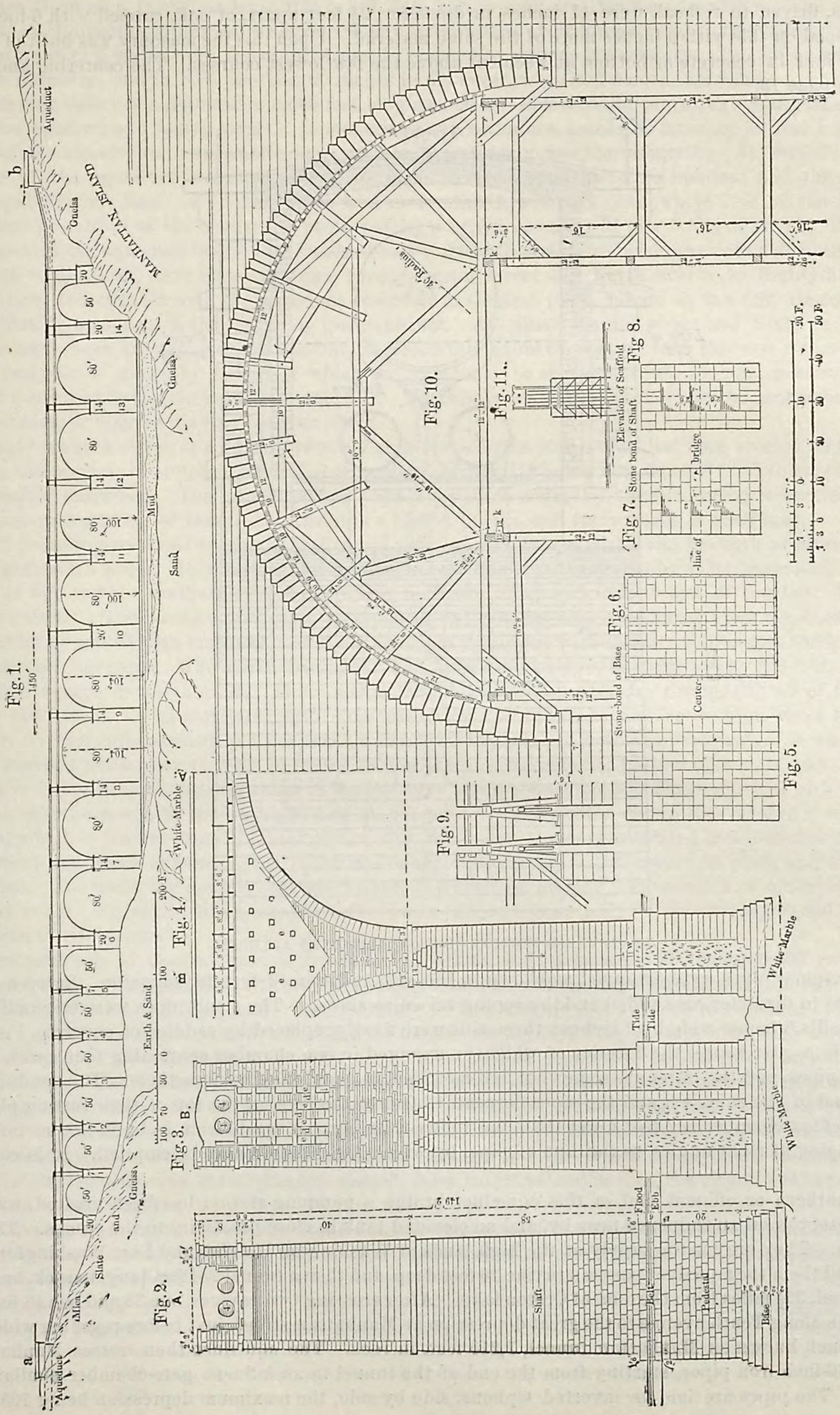
The next structure of importance is the great aqueduct bridge over the Harlem river, known as High bridge, 33 miles from the dam.



It was originally intended that the Harlem river should be crossed by an inverted siphon under the bed of the river, and this could have been built at a fraction of the cost.

The mainland bank here has a slope of 20°, and the island bank has a slope of 35°. The country rock is here gneiss, extending beneath the river at a sharp declivity, and the central depression between banks contains a deposit of white marble.

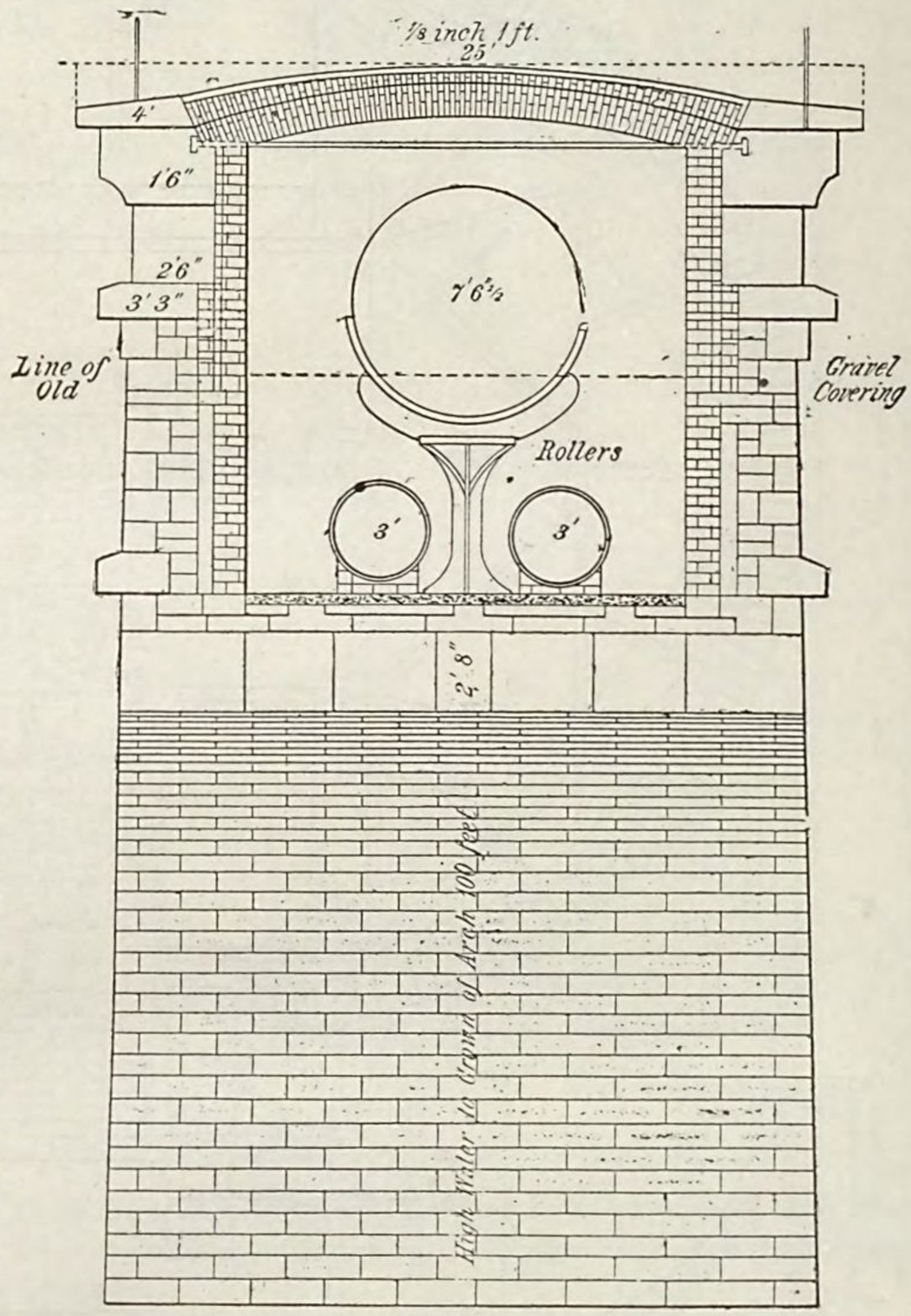
The bridge has fifteen arches—eight of 80 feet width by 100 feet height above flood-tide, over the water, while seven of them are upon the shores.



ELEVATION AND SECTION OF HIGH BRIDGE.

The two abutments and piers Nos. 1, 2, 13, and 14 are founded on gneiss, and 7, 8, and 9 upon marble, the remainder being upon piles. In this way the inverted-pipe siphon is depressed only 12 feet in crossing the bridge. To construct the water-piers, coffer-dams were built.

The piles, driven to refusal, were 11 inches in diameter, 2½ feet apart, of oak, capped with 6-inch planking, and cross-capped on this with 6 inches more of the same material. Upon this the masonry was built of gneiss rock, dressed and laid in concrete at bottom and cement above the few lowest courses. The centering and scaffolding are shown on page 13.



TRANSVERSE SECTION OF HIGH BRIDGE AS ALTERED.

The two original pipes were arranged as shown in the cut, and were 3 feet in diameter. Later a third pipe, 7 feet 6½ inches in diameter, was added and the coping raised as shown. The small pipes were originally laid upon small wooden sills 6 inches wide by 9 inches; these sills were finally replaced by saddles of concrete. At each end of the bridge is a gate-house, the interior of which is arranged in one chamber containing four gates, closing the mouths of the pipes, and the latter are somewhat bell-mouthed, to assist the flow into them. The conduit ends on a level in one end of the chamber, and the pipes descend 12 feet to the level of the top of their resting-places on the bridge. The efflux-chamber is 2 feet lower than the influx-chamber. A waste-weir is built in the influent gate-house, discharging at right angles to the line of pipe, by which the conduit may be emptied. It is controlled by iron gates.

At the southern or effluent end of this aqueduct bridge a pumping-station has been erected, with a small distributing reservoir on an eminence near by, and an elevated tank in close proximity to the pumps. These will be described later. They are for the supply of the high lands of Washington Heights and Fort Washington. A short distance beyond them the aqueduct passes a ravine 30 feet deep, and then a tunnel 234 feet long, in rock, and known as the Jumel tunnel, 33½ miles from the dam at Croton lake. After crossing two ravines, one 38 and one 43 feet deep, the conduit extends along Tenth avenue to the great depression at Manhattan street, just before reaching which it passes its longest tunnel, known as Manhattan tunnel, 1,215 feet, in rock. The aqueduct then crosses Manhattan valley through four 36-inch iron pipes, starting from the end of the tunnel in an influent gate-chamber similar to that at High bridge. The pipes are laid as inverted siphons, side by side, the maximum depression being 105 feet below

the grade-line of the aqueduct. The total length is 4,180 feet to the effluent gate-house on Asylum hill, opposite, and similar to that last mentioned. At the latter point the water enters again the continuation of the conduit, which passes through a tunnel under Asylum hill, 640 feet, in rock, to Glendenning valley. The aforementioned siphon-pipes in Manhattan valley have discharge- or waste-pipes at their lowest point in the valley, which discharge into the sewers over a waste-weir, the object being to empty the siphons if necessary. In 1854 an additional pipe, 48 inches in diameter, and in 1861 another, 60 inches in diameter, were laid across this valley.

Glendenning valley is a depression 2,000 feet long and 50 feet below conduit-level, extending from Ninety-sixth street to One hundred and fourth street. It was crossed on a viaduct, arches of masonry 30 feet wide being built over most of the streets, and two smaller ones of 9 or 10 feet each over the sidewalks. In 1875 this viaduct, and the portion of the aqueduct included with it between Ninety-second and One hundred and thirteenth streets, were replaced by four lines of 48-inch pipes laid under Tenth avenue. The whole line of the conduit where elevated above the level of the country is protected by a turfed covering of 4 or 5 feet of earth. Within the last few years most of the aqueduct below One hundred and thirteenth street has been removed or disused, and two iron mains, 6 feet in diameter, have been laid from Ninety-second street and Ninth avenue to Eighty-fifth street and Eighth avenue, and connect with the aqueduct reservoir in Central park, known as the Old Basin. In all there are 33 ventilating openings in the length of the aqueduct. At Ninety-second street and Ninth avenue two stone gate-houses have been erected over the conduit, at which the mains connecting with the new reservoir are joined. There are two sets of gates, by means of which the water may be sent either into the new reservoir through the conduit, or continued to the old receiving reservoir. The whole contents may therefore be sent to one or the other of the reservoirs, or may be divided between them.

At Ninety-seventh street and Ninth avenue a high-service pumping-works has been erected on the line of the conduit, for the purpose of supplying the higher portions of the city below One hundred and thirtieth street. This will be hereafter described. The aqueduct has been a constant source of trouble, owing to breakages and leaks caused by unequal settling of the ground through which it passes, and its capacity is overtaxed.

The old receiving reservoir is located in Central park, on the lines of Sixth and Seventh avenues and Seventy-ninth to Eighty-sixth street. It is rectangular in plan, in two divisions, separated by an embankment. The northern division is 24 feet and the southern 29 feet deep, and both are filled to within 4 feet of the top. Its capacity is 150,000,000 gallons. The banks are of earth with puddle interior, the sides bordering upon the lines of the streets and avenues being walled with masonry, and the inner faces riprapped with dry stone 15 inches thick. The bottom is of natural rock or earth. The north basin, and the larger of the two, is about 930 by 645 feet, and the south basin 645 feet square on the bottom. The division bank is also faced with dry riprap, and all of the faces slope 1½ to 1 on the inside. A 2½-foot pipe, with stop-gate, with its bottom 15 feet below high-water surface, passes through the division embankment and keeps the water-level the same in both compartments. A waste-weir in one end of the division bank allows excess of water to flow over its top into the bottom of a well, and thence into the sewer. There is one influent gate-chamber in the northern basin connected by a sluice channel with the other, and four effluent chambers, one on the east and one on the west of each basin. From this reservoir, which was built in 1840, and which is 6 miles from the end of the city, the mains formerly extended to a distributing reservoir at Fortieth street and Fifth avenue. This latter is a heavy cut-masonry basin, square in plan, and 400 feet long at the water-line. The walls are double, and are connected by arches, leaving a long series of chambers through the heart of the work. An earth filling supports the water-face or riprap wall. Capacity 24,000,000 gallons. It is probably soon to be removed.

The new reservoir in Central park is irregular in outline, with a capacity of 1,200,000,000 gallons. It is in embankment chiefly, with a puddle-wall through the center and a division-wall separating it into two basins. Area of water-surface 96 acres, depth 36 feet. The banks are 18 feet wide at top, slope 1½ to 1 inside. The puddle-wall rises to 2 feet above high-water mark. Division embankment 12½ feet wide at top, with both slopes, as well as those of the banks of the reservoir, faced with riprap of rubble in cement, 18 inches thick, on a foundation of 8 inches of concrete. The influent and effluent gate-houses of masonry are located at opposite ends of the division-wall. The aqueduct enters the former at the northerly end of the division-wall, and the water can be sent into either division. Effluent pipes, four in number, leave the northern gate-house, and are 36 inches in diameter. Another effluent gate-house at the southern end of the reservoir has six 48-inch supply-pipes leading from it.

The total revenue derived from "Croton water", from its introduction into the city in 1842 to September 18, 1880, amounts to $36,363,953.

The following statement shows the total amount expended for works, structures, aqueducts, pipes, etc., connected with the water-supply of the city of New York, including maintenance and repairs, from the period of its inception to January 1, 1880:

To January 1, 1865	$20,030,221 93
During the year 1865	224,337 27
1866	442,628 05
1867	581,794 80
1868	726,437 40

During the year 1869	$894,628 19
1870	1,172,078 48
1871	2,784,440 72
1872	1,836,847 68
1873	2,049,850 51
1874	1,465,708 03
1875	882,777 64
1876	1,066,645 50
1877	859,670 68
1878	802,014 58
1879	619,221 00

Total to September, 1880, $37,212,995.

The supply from Croton river, which was analyzed by Prof. C. F. Chandler, and the water of the Housatonic river, one of the proposed sources for increased supply, show the following indications of purity:

		Housatonic.	Croton.
Chloride of sodium	grains.	0.2019	0.284
Sulphate of potash	do...	0.1300	0.205
Sulphate of soda	do...	0.1842	0.024
Sulphate of lime	do...	0.0489	0.024
Carbonate of lime	do...	3.0362	1.698
Carbonate of magnesia	do...	1.5430	0.935
Alumina and oxide of iron	do...	0.0816	0.058
Silica	do...	0.5540	0.222
Organic and volatile matter	do...	0.5832	0.874
Total solids	do...	6.3630	4.324
Hardness	degrees.	3.6	2.5
Free ammonia	parts in 1,000,000.	0.0210	0.0700
"Albuminoid ammonia"		0.0674	0.2450

The works at High bridge for the high service of Washington Heights, etc., consist of an engine-house, boiler-house, and coal-shed, force-main to reservoir, small reservoir, and an auxiliary pump supplying a tank on the top of a tower. The engine-house, of brick and stone, is 40 by 25 feet, and arranged for two engines. The water is drawn through two 30-inch iron pipes 115 feet long, from a chamber about 4 feet wide connected with the aqueduct a short distance after its exit from the effluent chamber on the bridge. There are two pumping-engines, designed by William E. Worthen, of New York, one built in 1870, by the Hartford Foundery and Machine Company, and the other in 1876, by the Delamater Iron Works of New York. The former cost, in the prosperous times of 1870, about $40,000, and the latter only $29,000. Their capacity is about 5,000,000 gallons per day, and they are run alternately during the whole day. They are condensing-engines with a duty of from 25,000,000 to 35,000,000 foot-pounds, with single-acting pumps, plunger displacement. When the present improvements are completed there will be two multitubular boilers for these engines. Each is 17 feet long by 7 feet diameter of shell, with ninety-six 4-inch tubes in each, and operated at 45 pounds pressure. From the pumping-station two 20-inch force mains extend to the reservoir, 900 feet distant. The latter, of 10,000,000 gallons capacity and situated 216 feet above datum, is in embankment with a central puddle-wall 16 feet high, 4 feet thick at top and 10 feet at bottom. It is square in plan, measuring 322 feet at the high-water line. Inner slope 1½ to 1, outer 2¼ to 1; width of banks 12 feet on top. The inner face is riprapped 18 inches thick with rubble in cement laid upon the earth banks direct. The water-line is 2 feet below the tops of the banks, and the high-water depth is 16 feet. A small Worthington pump located near the reservoir takes water from the conduit or aqueduct and forces it into a tank of 44,000 gallons capacity at the top of a brick and stone tower, 335 feet above datum, and 160 feet high to water-line. The tank is of wrought iron, and is intended to supply a few very elevated points in the vicinity. The total cost of this double high service at the High bridge, including reservoir, tank, engines, tower, etc., amounted to $610,000.

The high-service works at Ninety-seventh street and Ninth avenue, on the line of the former Glendenning bridge, consist of a brick building 50 by 200 feet, extending from Ninety-seventh to Ninety-eighth street; at one corner, on Ninety-eighth street, a stand-pipe, inclosed in an ornamental square brick tower, rises 170 feet. Here are two Worthington engines drawing their supply from a 48-inch main from the new receiving reservoir through Ninety-eighth street. They are of large capacity, capable of pumping, according to records of the engineer, over 8,250,000 gallons per day. Only one is run at a time during 24 hours per day. Space is left in the engine-house for another. The dimensions are as follows: Steam-cylinder, low-pressure, 36 inches diameter; steam-cylinder, high-pressure, 21 inches diameter; water-pistons, 28 inches diameter; stroke, 48 inches; back pressure from reservoir, 7 feet; pressure on pumps averages 37 pounds; air-pumps, 16 inches diameter by 16 inches stroke; condenser, 28 inches diameter by 48 inches high; 4 boilers, 6 feet diameter by 15 feet long, containing seventy-five 3-inch tubes in each; average steam-pressure, 45 pounds. The stand-pipe, of wrought iron, is 170 feet high by 6 feet diameter, with a spiral staircase around it inside of the brick casing. Water is forced into it at present to the height of only 120 feet. It has one 36-inch inlet and one 36-inch outlet. The distribution, which amounts to

506 miles, is carried out through iron pipes, most of which, from 1858 to 1870, have been coated inside and out before laying, save a few laid in 1870 to 1874, which were not thus coated. They are of 4 inches to 48 inches diameter, and are tapped up to 20 inches only. The consumption approximates 95,000,000 gallons per day.

There are in all 6,210 fire-plugs in the city, mostly of the Ayres pattern, patent hydrants being forbidden by law.

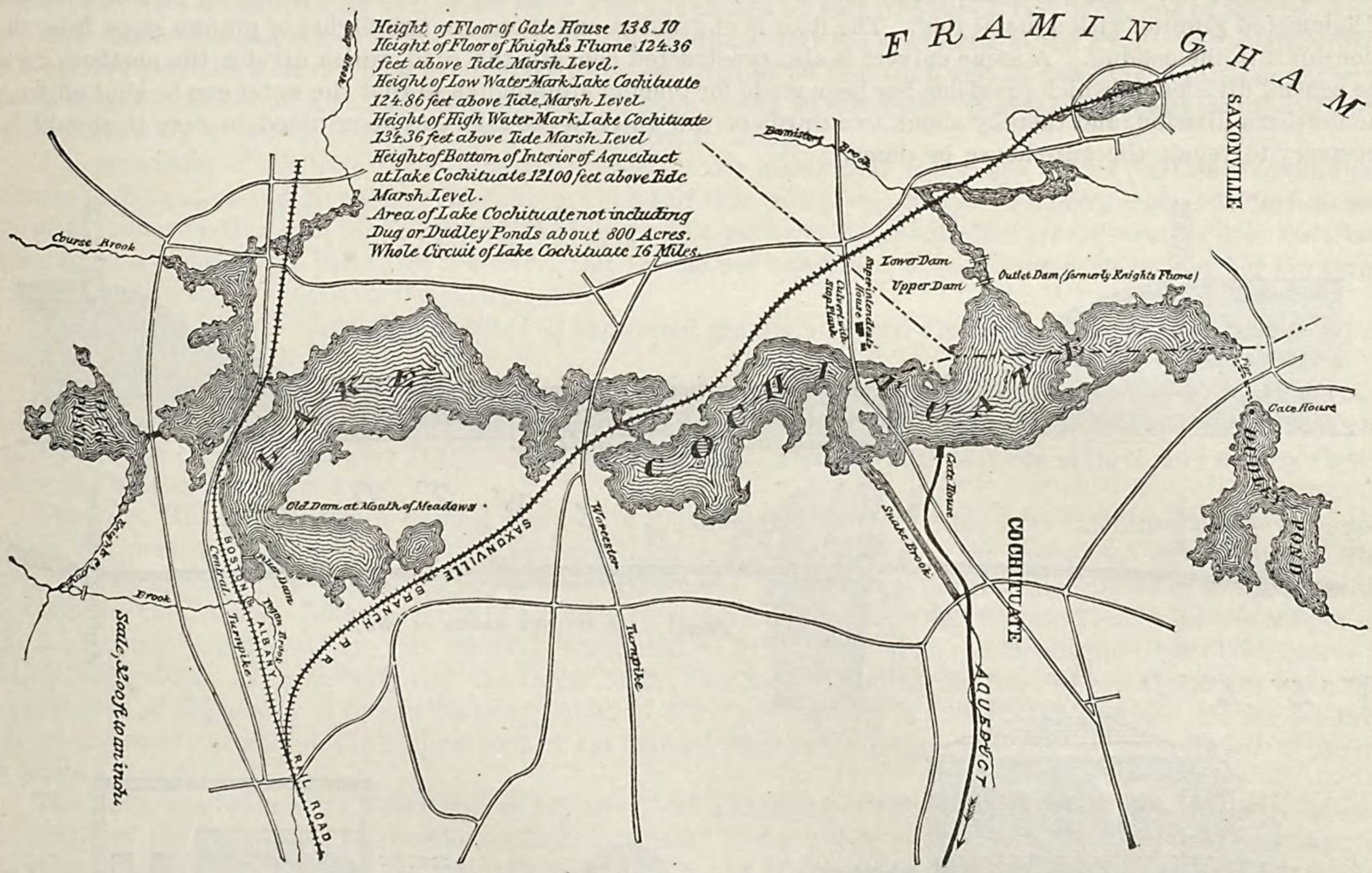
The annual cost of maintenance and repairs amounts to about $200,000, and the city pays nothing for water consumed in the public buildings and places.

Rates are assessed upon the frontage of lots, with special rates for various industries and establishments. By meters, of which there are 3,313, the rate is 7½ cents per 100 cubic feet.

The works are under the charge of Isaac Newton, C. E., as chief engineer, with G. W. Birdsall as first assistant engineer.

BOSTON, MASSACHUSETTS.

Boston contains 362,839 inhabitants. In addition to the ancient "Tremont", or Boston proper, the present city limits embrace several formerly independent towns and cities, notably Roxbury, Charlestown, and Dorchester. In the older portions the streets are proverbially irregular, while the topography is uneven. Water was introduced into the city in 1848. The system as at present existing is a gravity supply. Lake Cochituate, the main source of supply, is a chain of natural subsiding reservoirs of water, three in number, having a general direction nearly north and south (see map), its extreme length in a direct line being about 3½ miles, and its greatest breadth about 1,800 feet. Two county roads crossing it divide it into three nearly equal parts, designated as the northern,



MAP OF LAKE COCHITUATE.

central, and southern divisions. The water gradually increases in depth from the shore in each division; at high water, or when raised 10 feet above the flume, or 13.36 feet above the bottom of the conduit, its greatest depth is about 72 feet in the southern, 50 in the center, and 64 feet in the northern division. When the water is at this elevation, the superficial area of the lake is estimated to be 800 acres. At 3 feet 5 inches above the bottom of the conduit the area of the lake is 490 acres, and its capacity is 13,313,000 wine gallons; for every inch added to the above height up to 5 feet there is an increase of 1 acre in area, and the total capacity is increased to 270,834,000 wine gallons. At 13.36, or high-water mark, the total capacity of the lake is 2,011,165,000 wine gallons, and the area 801 acres. The shore of the lake is generally a bold sand and gravel bank, and the increase of surface which

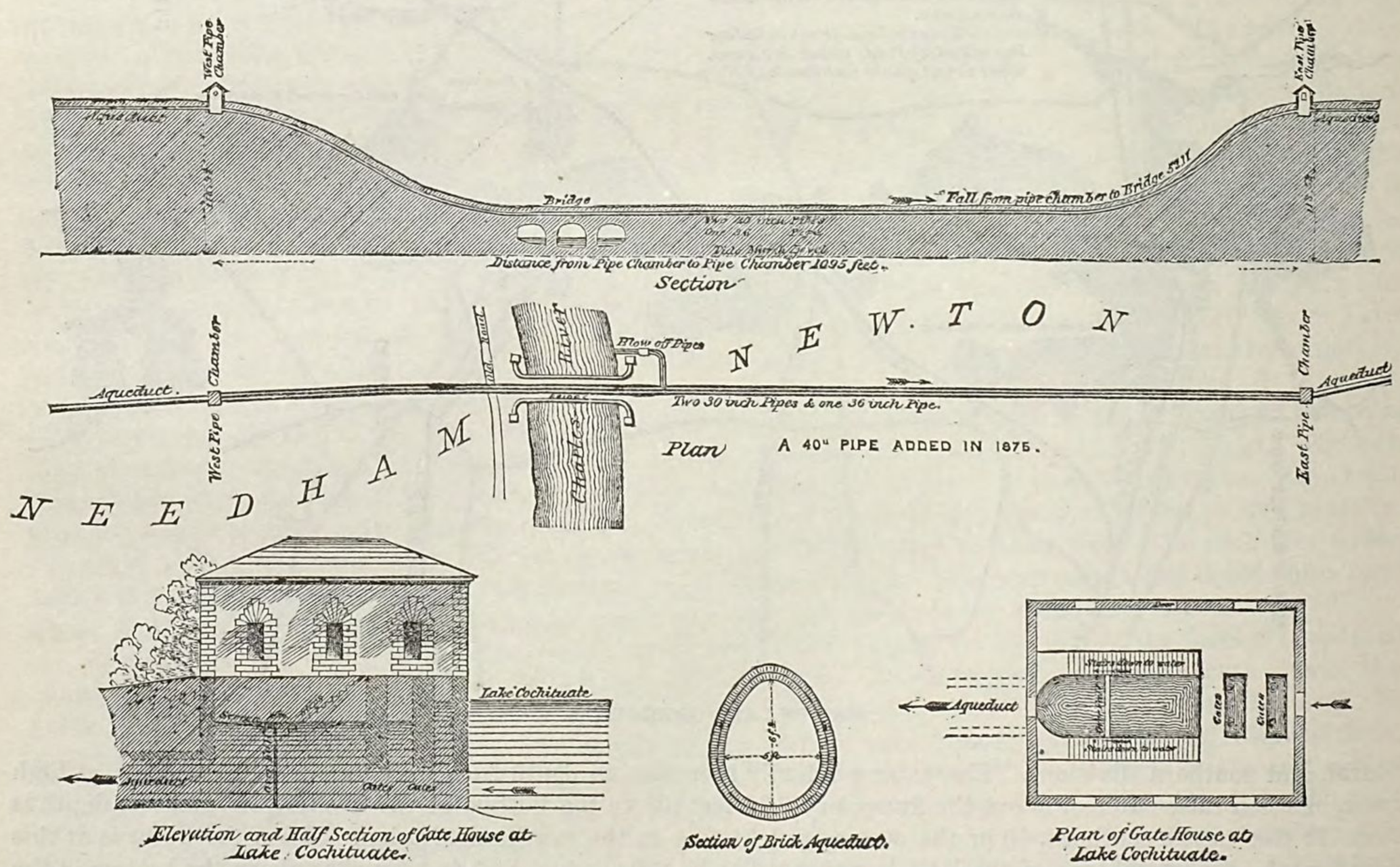
is produced by raising the water takes place mostly in a great meadow in the southern division. The whole circuit of the lake, including the meadows, is about 16 miles, and, excluding those, about 12 miles, measured at the verge of the lake, when the water is 8 feet above the flume.

The tract of country which drains into the lake is bounded by the ranges of hills which divide the streams running into the Merrimack from those which run into the Charles river, and, as surveyed, covers an area of 11,400 acres, or 496,584,000 square feet, as the water-shed from which the lake derives its supply.

The flume referred to above was known as "Knight's flume", and was used for manufacturing purposes. The floor of this flume was 3.36 feet above the bottom of the conduit; the waters of the lake were at first raised to 8 feet above the floor of the flume, but afterward to 10 feet, the cost of the last 2 feet being $27,130, which included the damages paid for submerged lands.

There are two dams at the outlet, which is on the west side of the northern division. The first is of solid masonry or granite, and raised to a height sufficient to retain the water to a point 10 feet above the floor of the flume. This corresponds with an elevation of 134.36 feet above tide-marsh level, the floor of the flume being 124.36 feet above the same level. The second dam is at a distance of about 500 feet below the first, and is for the purpose of lessening the pressure upon the upper dam; it also is of solid masonry, with an overflow of 23 feet in width.

The gate-house at the lake is situated on the eastern side of the northern division opposite to the dam, and is built a sufficient distance into the lake to admit the water from the necessary depth. The bottom of the aqueduct, which here begins, is placed at an elevation of 3.36 feet below the floor of the flume. When the lake is raised to the high-water mark it will stand 13.36 feet above the bottom of the conduit. In the house there are four gates for regulating the admission of water into the aqueduct. They are of cast iron, with composition or gun-metal facings, and a frame of the same materials, set in hammered stone. This building is 29 feet 6 inches by 39 feet 6 inches, of hammered granite, with a metal roof. The floor is of granite, and there are two flights of granite steps from the floor down to the conduit. A stone culvert is also constructed beneath the road, which divides the northern from the central division, in which provision has been made for placing stop-planks so that the water can be shut off from the northern division, and thereby about two-thirds of the water in the lake can be retained in case it should be necessary to repair the gate-house or dams.



PLAN AND SECTION SHOWING METHOD OF CONVEYING WATER ACROSS CHARLES RIVER.

Dug pond is south about 113 feet from the southern shore of the lake, and is separated from the peat meadow, on the southern division, by the county road; a culvert, 2 feet in diameter, is laid beneath the road, by which the waters are discharged into the meadow and thence pass into the lake; the pond contains about 44½ acres. The shore all around is a steep gravelly bank, 8 or 10 feet high, and the pond naturally derives its waters wholly

from springs. The water is quite deep and remarkably pure and soft, and forms a highly important tributary to the lake. High-water mark in this pond is 17 feet above Knight's flume. The town of Natick now obtains a supply from this pond, so that its value to the city has been somewhat diminished.

Dudley pond lies in a northeastern direction from the northern division of the lake, and contains 81 acres, at an elevation of about 12 feet above the lake. There is no other outlet than that through which it flows into Sudbury river. This pond was connected with the lake in the year 1861, by means of iron pipes 18 inches in diameter and about 800 feet long, which pass under the road. High-water mark in this pond is 22.1 feet above Knight's flume, and 146.46 feet above tide-marsh level.

The aqueduct, for convenience in its management, is divided into two divisions, the western and the eastern. The western extends from the lake to and including the receiving reservoir in Brookline. The eastern begins at the Brookline reservoir, and comprises all the iron mains from Brookline to the city and the distribution in the city.

The conduit, from the lake to the left bank of Charles river, and from the right bank of the same to Brookline reservoir, is built of brick masonry 8 inches thick, laid in hydraulic cement. It is in section an egg-shaped oval, the larger end down; the greatest width is 5 feet, and the extreme height 6 feet 4 inches in the interior. It is covered with a plastering of hydraulic cement on the outside, from the top down to the chord-line of the lower or inverted arch. It is supported on a puddled embankment, built up above the chord-line of the inverted arch in all cases where the aqueduct passes over ground the level of which falls below the grade-line, and also where the ground was found to be marshy, or from any cause not sufficiently solid to support the superstructure. The whole is covered with an embankment 8 feet wide on the top, with side slopes of 2 feet horizontal to 1 foot vertical, and raised 4 feet above the top of the aqueduct. The aqueduct through the whole distance thus rests upon and is covered with earth to a depth of at least 4 feet, and is nowhere raised so as to admit a passage beneath it excepting at the culverts—at the crossing of Charles river, which it passes by four iron pipes, two of 30, one of 36, and one of 40 inches diameter—and where it crosses the valley in Needham near the west bank of the river. In the latter place it is carried over the roadway by a granite bridge of one arch of 20 feet span and 14 feet high, and from there to the west pipe-chamber on a puddled embankment, in some places 40 feet high. (For further details see the *History of the Boston Water Works*, published by the department in 1874.)

The remainder of this part of the aqueduct comprises the mains over the valley of the Charles river and the tunnels in Brookline and Newton. The former consist of four iron pipes, two of 30 inches, one of 36 inches, and one of 45 inches in diameter, which descend 52.11 feet below the level of the aqueduct on the west bank of the river, crossing on a stone bridge built over the river, and thence are continued over the intervale at a rather low level, and then rise to the aqueduct on the eastern side.

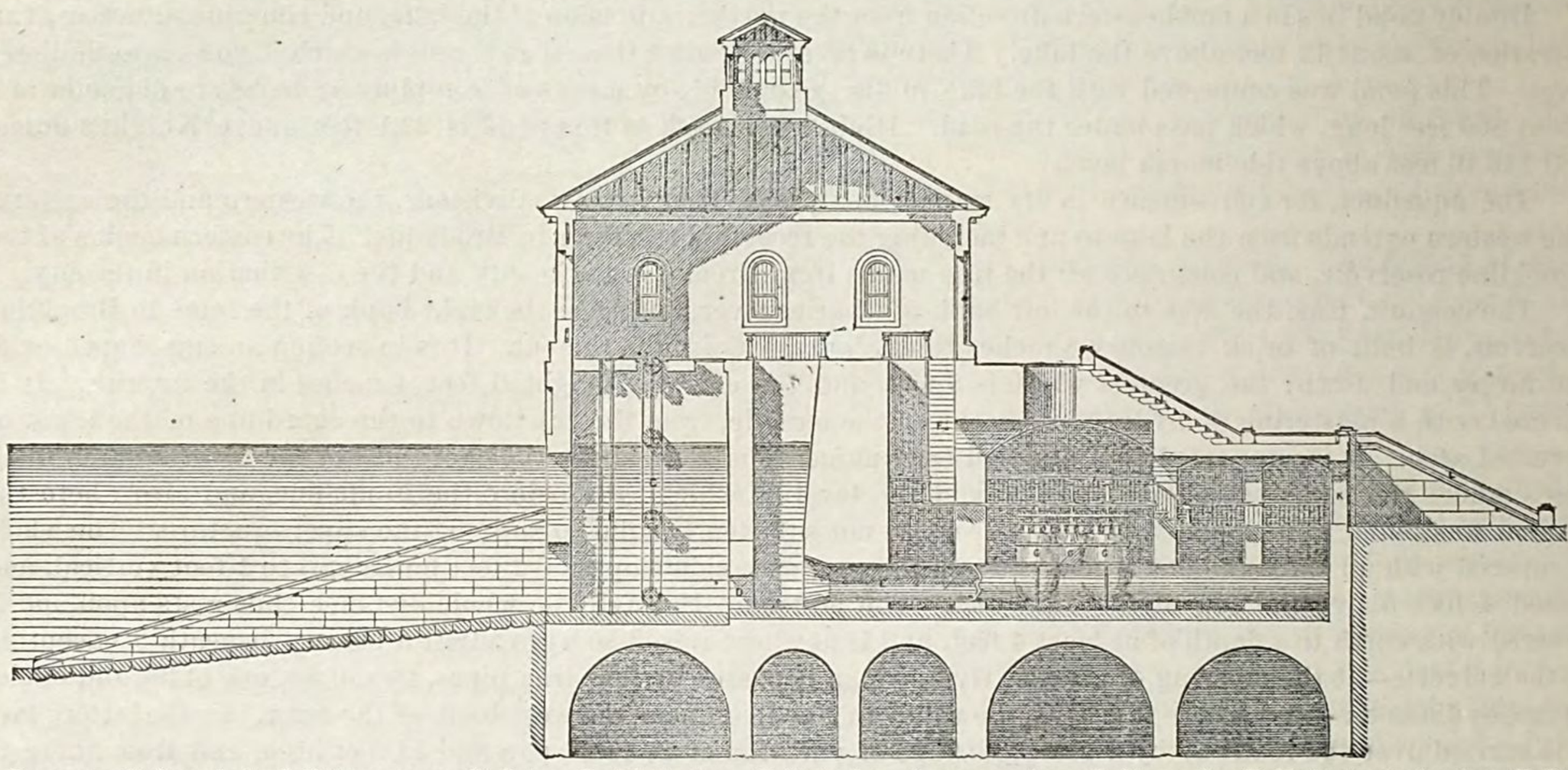
The Charles River bridge is constructed of hammered granite, of three elliptical arches, of 30 feet span and 7½ feet rise, and 21 feet wide.

The pipe-chambers, constructed at each end of the mains, are of granite; the horizontal distance between them is 1,095 feet. The admission of water is regulated by stop-planks. The bottom of the west pipe-chamber is 119.04 and that of the east pipe-chamber 118.58 feet above tide-level. The water in the river at its lowest state is 71 feet below the bottom of the brick conduit.

Chestnut Hill reservoir is a natural basin at a distance of about 5½ miles from the center of the city, and within the present municipal limits. An artificial bank was required only on the lower side of the valley. The reservoir is built in two parts, separated by a water-tight dam. A gate-house in the center allows of communication between the two basins. Both parts are of somewhat irregular form. Together they are 2½ miles in circumference. The land bought by the city for this reservoir amounted to 212½ acres. The combined capacity of both basins is 731,472,429 gallons. The easterly and the larger of the two basins is called the Bradlee basin, and has when full a water area of 87½ acres. Average depth of water, 20 feet. Its capacity is 550,583,485 gallons. On the easterly side of the reservoir and on the highest part of the embankment is the principal or effluent gate-house. It fronts on Beacon street.

The Lawrence basin has a water area of 37½ acres, and a capacity of 180,888,944 gallons. The distance around the center of the path which surrounds the Lawrence basin is 6,183 feet, or 1.17 mile. The effluent gate-house is the most important structure on the reservoir grounds. A bed of quicksand, 28 feet in depth, rendered the laying of the foundations a difficult task. Rubble piers with brick arches rest on the bed-rock and support the structure. These were leveled off on top with a layer of concrete; and a heavy bulkhead, side-walls, brick piers, and groined arches complete the remainder of the substructure. On the water side of the bulkhead are four separate compartments for four lines of 48-inch pipes. Each compartment has places for a double set of stop-planks, a revolving screen, sluice-gates, and an open well in front of the pipe. The superstructure is built of hammered granite. Outside of the bulkhead are gates placed in the pipes. Branch walls are built into the bank 80 feet long on one side, 25 feet on the other. Their section consists of 4 feet of rubble-wall laid in cement, and 2 feet of brick-work. Outside of this gate-house is a brick chamber under ground, which contains two gates. These control two lines of drain-pipes, which run through the embankment on arches. They connect with each basin, so that either can be drawn to its lowest level for cleaning or repairs.

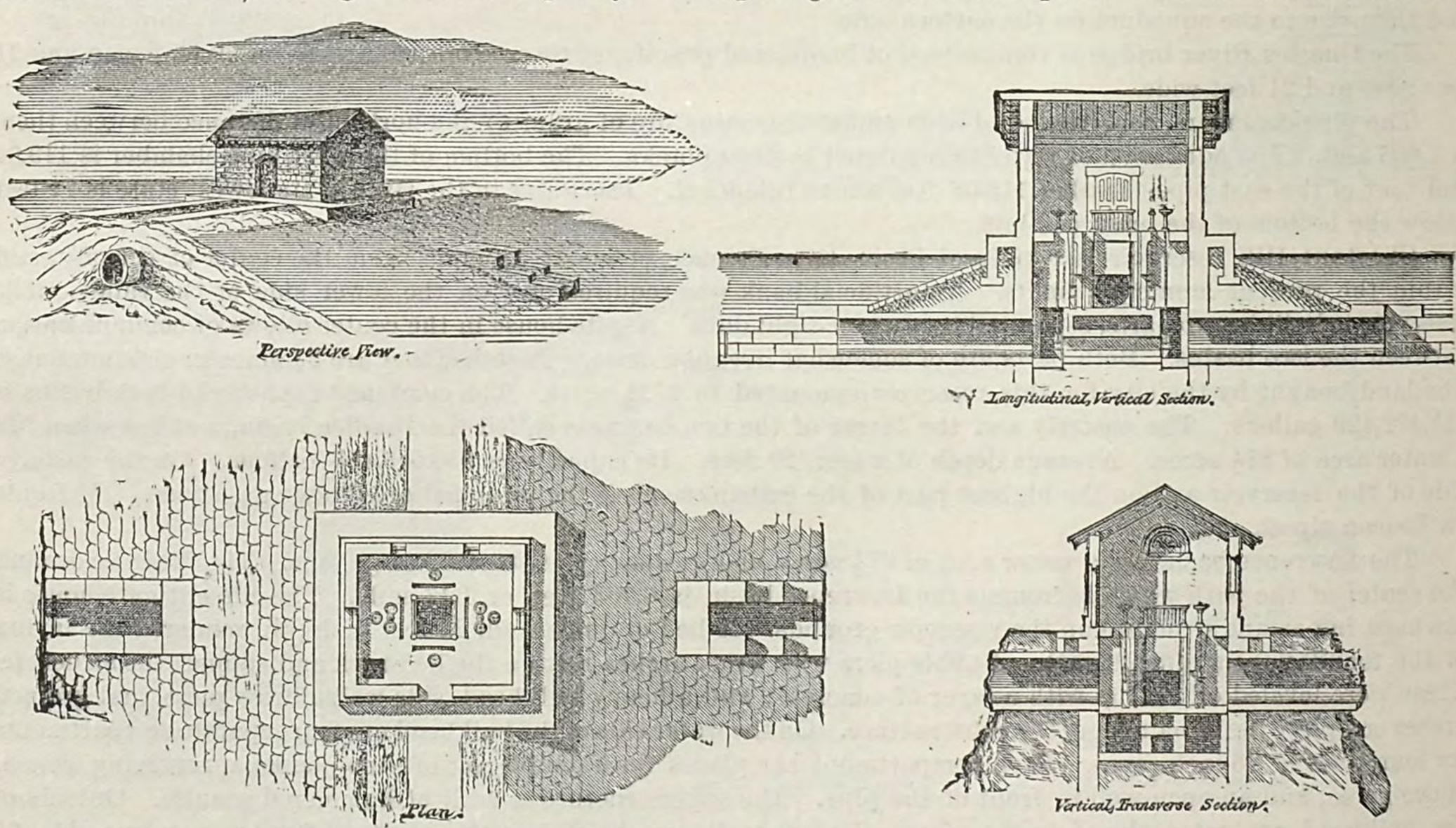
Two hydraulic sluice-gates worked by a hydrostatic press were placed in position during the winter of 1873–'74 in this gate-house. They are to shut off or let on the water to the 48-inch main. The need of gates at this point which can be quickly operated, has been felt ever since the reservoir was first used, and provision was made for



A, Reservoir; B, Stop plank; C, Rolling screen; D, Gates; E, 48-inch pipes; F, Stairs down from upper floor; G, Stop-cocks; H, Light pipe to chamber; K, Door under embankment; L, Steps up to gate-house.

LONGITUDINAL VERTICAL SECTION OF LOWER GATE-HOUSE AT CHESTNUT HILL RESERVOIR.

them when the gate-house was constructed. They have been designed with special reference to easy and rapid movement. One man can fully open either of them in less than 4 minutes, and they close by their own weight in less than 20 seconds, settling to their seats quietly. The openings are 48 inches square. The movement is vertical.

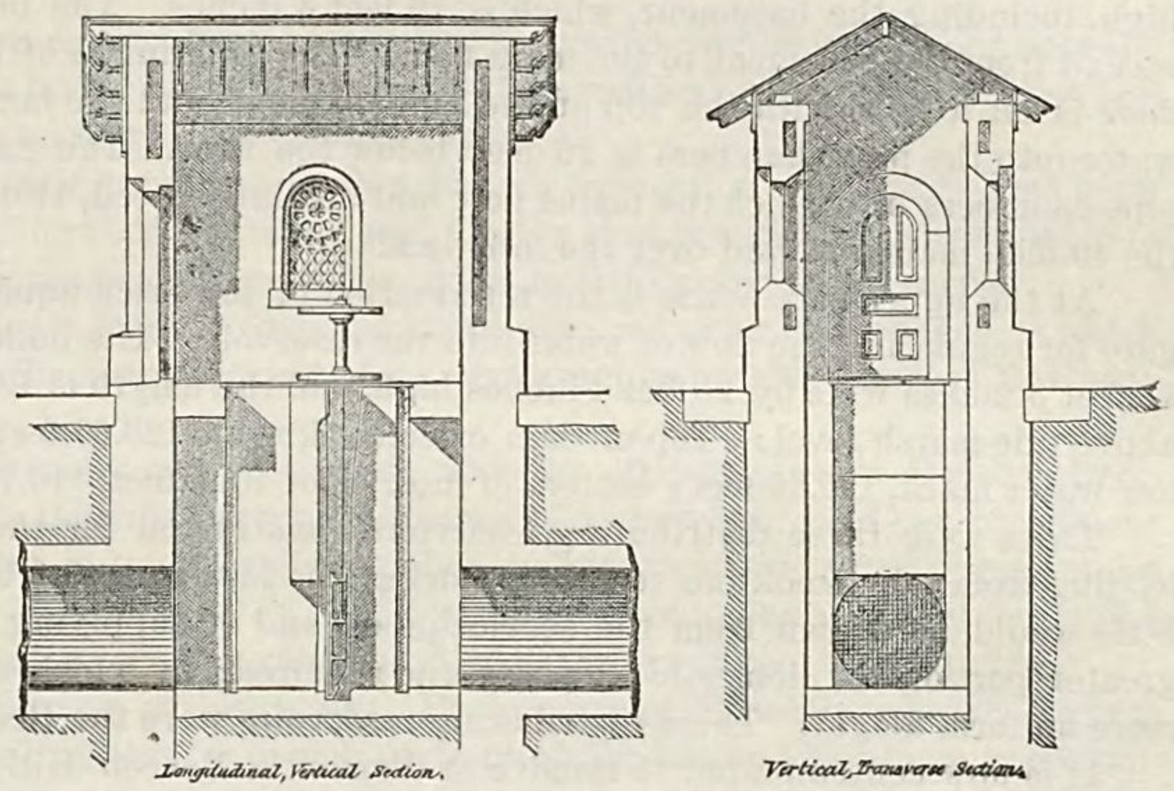


INTERMEDIATE GATE-HOUSE AT CHESTNUT HILL RESERVOIR.

When in motion the gates are carried on three pairs of wheels 12 inches in diameter. The seats are not exactly parallel to the gate-frame, being inclined slightly from the vertical, so that when the gate is closed the gate-face and seat are in contact, and the wheels are lifted a fraction of an inch from their tracks. Vertically over each gate is a cylinder fitted with a piston, 8 inches in diameter and of 4-feet stroke.

The intermediate gate-house, built in the center of the dam separating the two basins, is also located directly over the aqueduct, which runs lengthwise through the dam and continues to the Brookline reservoir. Four gates, one toward each basin and one on each end of the aqueduct, allow of turning the water any way. Beside these there are two lower-level gates connecting the two basins. There is also in one corner of this gate-house a gate communicating with a line of drain-pipe laid through the Bradlee basin.

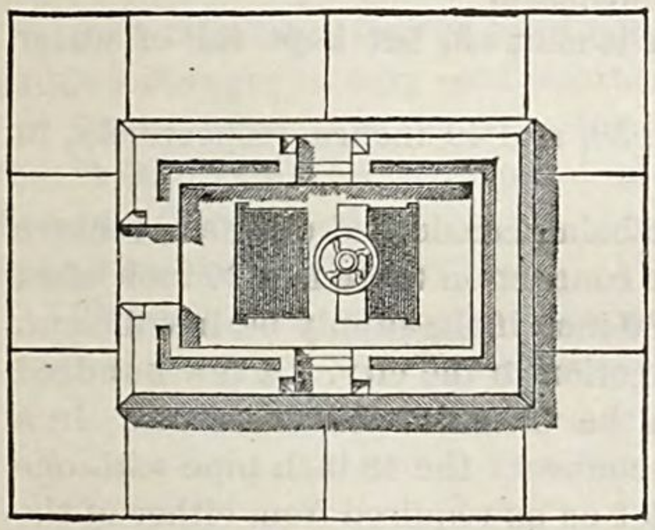
The influent gate-house at the Lawrence basin is the smallest of the three structures. It covers one gate that controls a connection between the aqueduct (which curves around one side of this part of the reservoir) and the basin. A short piece of brick aqueduct, 4 feet by 4 feet 4 inches, connects the two. A sewer is built to carry off the drainage of the valley, in order to keep it from entering the reservoir.



INFLUENT GATE-HOUSE AT CHESTNUT HILL RESERVOIR.

From the effluent gate-house a 48-inch main is carried around Fisher hill to connect with the pipes which supply the city from the Brookline reservoir, so that in case of any accident to that reservoir the city can be supplied from Chestnut hill. The length of this 48-inch pipe is about $1\frac{1}{4}$ mile. Its thickness is $1\frac{1}{4}$ inch. There are four gates at the junction of this pipe with the other mains; three, a 40-inch, a 36-inch, and a 30-inch connection, are together in one underground chamber; and a 48-inch gate on the main itself, which was put in in April, 1875, is a little back and separated from the chamber.

The Brookline receiving reservoir is situated at the eastern termination of the brick portion of the Cochituate aqueduct, in Brookline. It is formed out of a natural basin, inclosed almost entirely by banks rising to a considerable height above it. On the northerly side, however, there was no bank, consequently a puddled embankment was built up to a height of about 26 feet, and was supported by a retaining-wall 8 feet in height. The inner slope of the reservoir is lined with a slope-wall of granite rubble 18 inches thick and 14 feet broad, this lining rising to within 1 foot of the top of the bank. The greatest depth of water is near the principal gate-house, 24 feet. The least depth is near the upper gate-house, where it is about 14 feet. The embankment is 20 feet wide at the top, with a gravel walk all round. The area of the reservoir at a level of 6 feet below the top of the dam is 22.31 acres, and its capacity is 89,909,730 wine gallons, the contour of the water-line being 4,696 feet long. At 2 feet below the top of the dam it contains an area of 22.95 acres, and the capacity is 119,583,960 gallons; the contour of the water-line is, at this level, 4,757 feet. The reservoir is an irregular oval in shape.



MAP OF BROOKLINE RESERVOIR.

A cylindrical brick conduit is laid at a depth of 8 feet within the northern embankment, to connect with that from the lake, and conduct the water around the reservoir to the pipe-chambers, by means of which it was intended that the supply of the mains should be kept up when the water is shut off from the reservoir for cleansing it or for any other purpose.

There are two gate-houses, the upper for receiving the termination of the brick portion of the aqueduct, and the lower for the beginning of the iron main leading to the city, with regulating gates, gauges, etc.

The principal or lower gate-house has its front on the street, where it is 26 feet 4 inches wide by 36 feet 8 inches high, including the basement, which is 16 feet 4 inches. The height in the rear is 20 feet. Two iron stair-cases ascend from the basement to the main floor. The building is of hammered granite, with an iron roof. The main floor is on a level with the top of the embankment, and the bottom of the gates which regulate the admission of water into the pipe-chambers is 26 feet below the floor. The gates and gate-frames are of iron. There are three pipe-chambers into which the mains now laid are introduced, two only having been used until the year 1859, when the 40-inch main was laid over the mill-dam.

At the upper gate-house is the termination of the brick aqueduct, and it is fitted with stop-planks and a flap-gate for regulating the flow of water into the reservoir. The building is of granite, with a stone roof. The front is 11 feet 3 inches wide by 11 feet 4 inches high, and the length is 12 feet. The following are the heights, respectively, above tide-marsh level: Top of dam or embankment, 126.60 feet; upper floor of principal gate-house, 126.76 feet; low-water mark, 120.60 feet; bottom of interior of aqueduct, 116.76 feet; bottom of reservoir, 100.60 feet.

There were three distributing reservoirs constructed for the purpose of receiving the water from the mains leading from the Brookline reservoir during the latter part of the day and the night, when it was presumed but little would be drawn from the service-pipes, and of supplying it to the service-pipes in the morning, when the greater portion for domestic purposes was required; by which means a continuous supply could be kept up to a more uniform height. These distributing reservoirs were the Beacon Hill, South Boston, and East Boston.

It is now contemplated to remove or dismantle Beacon Hill reservoir and use the site for other purposes. It has not been in use since June 6, 1870, the high-service works at Roxbury supplying its object and the neighborhood for which it was especially constructed.

The high-service works at Roxbury has rendered the South Boston reservoir useless, and water has been shut off since July 15, 1872, but nothing has as yet been done regarding its ultimate disposal.

East Boston being now supplied from the Mystic department, the reservoir is shut off, but kept full of water in case of emergency.

The city is supplied from its distributing reservoirs by three iron mains, 36, 30, and 40 inches, respectively, in diameter, starting from the effluent gate-house of the Brookline reservoir.

When the gate-house was built an extra 30-inch outlet was provided, and, it being considered unsafe to remove it to substitute a 40-inch, the 40-inch main is connected with it, and on the taper connection there is a 20-inch inlet, now capped, which can be continued through the masonry bulkhead above the 30-inch if the supply be insufficient. After leaving the gate-house they pass into Boylston street, in an easterly direction to the city. A few hundred feet from the gate-house these mains connect with a 48-inch pipe leading from the Chestnut Hill reservoir. In a chamber near the road are three gates, each of which, by means of branches, connects the 48-inch pipe with one of the above mains, so that the supply from the Chestnut Hill may be cut off or let on as required from either of the mains. Between the Brookline reservoir and these connections there is a gate on the 30-inch pipe, to allow of the emptying of the Brookline reservoir without interfering with the supply from Chestnut hill.

The Beacon Hill district, comprising about 48 acres, and necessitating a high-service supply, is furnished with a 20-inch main, taking off the 24-inch main from the Parker Hill reservoir.

The South Boston low service is supplied by two 20-inch pipes. One of these, taking off from the 36-inch main, crosses the Fort Point channel at the Dover Street bridge; the draw is passed by a siphon, the distance between the arms of which is 41 feet. A trench was excavated into the hard bottom of the channel 32½ feet below the top of the bridge, and the siphon was laid in a box filled in with hydraulic cement. This main runs to the reservoir on Telegraph hill. The second 20-inch main leaves a 24-inch main in Dorchester and passes to the reservoir on Telegraph hill. The two mains connect at the corner of Atlantic and Thomas streets. The reservoir is not now used, as has been stated.

The South Boston high service is fed by a 12-inch pipe leaving the 20-inch high-service pipe in Boston proper at Berkeley street, and connects with the South Boston high-service pipes opposite the reservoir. This pipe crosses the Fort Point channel at the Dover Street bridge, with an inverted siphon. The siphon is made of 16-inch pipe, and is laid in a box surrounded by concrete.

The district of East Boston is supplied by a 20-inch main, which leaves the 24-inch main in Boston proper in Haymarket square. On its route to East Boston it crosses Charles river, over the Warren bridge, passing the draw by an inverted siphon having a dip of 36 feet and a distance between the arms of 39 feet. It continues through Charlestown, where it has two connections with the Mystic works, and crosses to Chelsea over the Chelsea bridge, where it passes under two draws. At the southerly draw the siphon dips 34 feet, with a length of 50 feet; at the northerly draw the dip is 42 feet 5 inches, and the distance between the arms is 50 feet. All the siphons are inclosed

in wooden boxes and are protected with concrete. In Chelsea this main has two connections with the Mystic works. From Chelsea it passes to East Boston across Chelsea creek to Brooks street. The creek is crossed by means of flexible jointed pipe, 461 feet long. The flexible portion of the pipe was laid in a trench, dredged to about 6 feet in depth, and covered with clay and gravel to protect it. The creek itself is about 1,600 feet wide. The flexible joints were movable only in a vertical plane, and were adopted by Mr. William S. Whitwell, the engineer. In 1871 a new main, 24 inches in diameter, was laid across the creek, and was connected at each end with the 20-inch main. From Chelsea creek the main passes on to the reservoir, whence the distribution takes place through a 16-inch pipe.

This service is principally supplied from the 24-inch Dorchester main, leaving the 30- and 36-inch mains near the Boston and Providence Railroad crossing. One 12-inch branch leaves the 24-inch main also near the crossing, and passes through Roxbury by the side of the 24-inch main on its way to Dorchester.

The pumping-engines on Elmwood street take their supply through a 16-inch connection with the 24-inch main in Roxbury street. A 16-inch force-main through Elmwood, Gardner, and Center streets and Fort avenue leads to the stand-pipe. From this 16-inch a 24-inch pipe branches off at Center street to the Parker Hill reservoir.

Dorchester receives its supply from a 16-inch main leading from the stand-pipe, reducing to 12 inches, at which size the mains extend. This supply is derived from the 24-inch main before mentioned as passing through Roxbury, terminating at Dorchester avenue.

The Brighton low service is supplied by a 16-inch main connecting with the 40-inch pipe on Beacon street. This pipe crosses the Boston and Albany railroad in Brighton avenue by means of an iron bridge of two continuous plate girders, each 137½ feet long. The high service is temporarily supplied by means of two small pumps and a reservoir, drawing their supply from a low-service 12-inch pipe in Brighton. The force-mains are 12 inches and 8 inches, respectively, in diameter, and the supply-mains are 12 inches and 6 inches, respectively, in diameter.

The Boston system embraces the following districts or localities: Boston proper, Brookline, South Boston, East Boston, Roxbury, Dorchester, West Roxbury, Brighton, and such portions of Newton and Needham as contain pipe connected with the Boston works.

Exclusive of the above, and belonging to the Mystic department, but under the control of the Boston water-board, are Somerville, Medford, Charlestown, Chelsea, and Everett. These will be treated of in the space devoted to the Mystic department.

The maximum loss of head between the Brookline reservoir and the city is about 25 feet, which occurs only in sudden changes to very cold weather, and is due to waste from the service-pipes, to prevent freezing.

There have been used in Boston many kinds of hydrants, among which might be mentioned the Lowell, the Ballardvale, the Wilmarth—now known as the Boston—the Kingston, the Hooper, and, more recently, the Lowry. Those used to-day are comprised under the three heads of Lowry, Boston, and Post, and the majority in use are flush-hydrants.

The following table gives the number of hydrants set in Boston up to January 1, 1878:

Districts.	Lowry.	Boston.	Post.
City proper	429	874	10
South Boston	128	348	.....
East Boston	99	185	6
Roxbury	651	103	13
Dorchester	553	42	34
West Roxbury	84	19	175
Brighton	57	13	116
Total, 3,939	2,001	1,584	354

The following statement shows the number of hydrants in use in the Mystic department up to 1881:

Districts.	Lowry.	Flush.	Post.	Total.
Charlestown	169	34	35	238
Chelsea	.....	5	131	136
Somerville	3	26	253	282
Everett	1	.....	68	69
Medford	.....	5	5	10
Total	173	70	492	735

The most popular meter in Boston at the present time is the Worthington. It is giving general satisfaction. The sizes in use in this city range between ⅝ inch and 4 inches, and in the total number of 1,082 there are 686 ⅝-inch, 333 1-inch, 46 2-inch, 13 3-inch, and 4 4-inch.

A few of the class known as the Johnson meter are in use. This is a single-piston meter manufactured in Boston, and is comparatively new.

THE MYSTIC DEPARTMENT.

One of the factors in the Boston water-works system is the Mystic supply, once operated by a distinct management, and designed originally for the supply of Charlestown and Chelsea, the northeasterly suburbs of Boston proper.

On April 13, 1854, several gentlemen, interested in the Cambridge water-works, procured from the legislature the right to supply Charlestown with water, under the name of the "Charlestown Water Works". The increasing requirements of the city had made it evident that more energetic action was necessary, and in August, 1859, the city council authorized Mayor Dana to obtain a charter to supply the city with pure soft water. Messrs. George R. Baldwin and C. L. Stevenson were appointed engineers, and detailed scientific examinations were made of all the sources within 15 miles of the city. These resulted in the report that only Spot and Mystic ponds were available. Spot pond, from the favorable conditions belonging to it, in its elevation, position, and purity, has undergone more minute examination than any other source in the neighborhood.

In 1845, Mr. J. B. Jervis, engineer of the Croton water-works, and W. B. Johnson, civil engineer, having been appointed water commissioners for Boston, found the yield of Spot pond to be 1,500,000 gallons per day, derived from a drainage area of 1,100 acres, the extreme elevation of the pond accounting for the limited drainage area.

Mystic lake, from the upper or northerly portion of which the supply is taken, is located in the towns of Medford, Arlington, and Winchester, 6⅗ miles from Charlestown square. At the level of flowage authorized, it has an area of about 200 acres, with a storage capacity of 380,000,000 gallons of water. The area of the drainage basin of the Mystic lake is 27.5 square miles. The numerous ponds in the basin serve to check the too-rapid discharge of the rainfall into the lake and thence into the river; but, nevertheless, the discharge is rapid. The geological characteristics of the basin are, that the greater part of its length and breadth is composed of a deposit of gravel and sand of a considerable depth, underlaid with primitive trap of the common greenstone variety, which crops out on the hills occasionally.

From the report of the chief engineer, published in 1865, we note his estimate of the safe daily available yield of Mystic lake to be 30,000,000 gallons.

The following table gives the rainfall and approximate quantity of water daily consumed from the Mystic works since 1866:

Year.	Total yearly rainfall.	Approximate daily quantity of water consumed.	Remarks.
	Inches.	*Gallons.*	
1866.....	40.48	1,000,000	
1867.....	42.10	1,300,000	Extended to Chelsea.
1868.....	40.12	1,000,000	Extended to Somerville.
1869.....	37.71	2,500,000	
1870.....	24.65	4,000,000	Water let on to East Boston.
1871.....	24.84	5,000,000	Extended to Everett.
1872.....	45.71	6,800,000	
1873.....	48.60	7,700,000	
1874.....	34.14	7,600,000	57,000,000 gallons supplied, in all, to Boston.
1875.....	48.06	7,500,000	East Boston shut off from April 21 to December 2.
1876.....	47.00	8,825,000	
1877.....	41.60	8,378,000	

The rainfall was measured at Mystic lake.

The Mystic valley, besides containing a large population within its limits in the form of small towns or otherwise, whose sewage up to the present must in large part have naturally found its way to the lower levels, is the site of some 82 factories—more than a third of which are tanneries—employing some 3,500 hands. The refuse from this large manufacturing interest, situated as the tanneries must be, on the banks of the streams, also finds its way into the lake.

Professor E. N. Horsford, of Cambridge, in his report on the analysis of the Mystic water in 1873, says: "Of its salubrity as a drinking-water, it will compare well with the best waters in use for city supply. It has experienced no appreciable deterioration since its introduction."

The Mystic system comprises: Dam and overfall; conduit, gate-houses, waste-weir, etc.; cast-iron mains under Mystic river, bridge, etc.; engine-house and pump-well; pumping-engines; force-main; reservoir and appurtenances; supply-main and city distribution. A detailed description may be found in the report of 1874, before mentioned. The pumping machinery only will be here mentioned.

The pumping-engines in the Mystic pump-house are of the Worthington make, three in number, two of 5,000,000 and one of 8,000,000 gallons capacity. One of the former was erected in 1865, the other in 1866, and the third in

1872. The diameter of the steam-cylinders of the former are 43.3 inches for the low and 25 inches for the high pressure. Length of stroke, 48 inches.

Of the 8,000,000-gallon engine, the low-pressure cylinder is 50.25 inches and the high pressure 29 inches diameter. The average velocity is 44 strokes per minute. The smaller engines have plungers 22 inches in diameter with 48-inch stroke, and the larger 28 inches in diameter with 50-inch stroke. These engines are driven by a set of horizontal multitubular boilers 16 feet long by 5 feet 3 inches in diameter, containing eighty 3-inch tubes in each, and fired at a pressure of 45 pounds. With the Cumberland coal used they evaporate 10.2 pounds of water per pound of coal.

The force-main is 3,277 feet in length. The level of this main at the engine-house is 16 feet 6 inches above tide-water, and it rises gradually to the reservoir, in which the level of high water is 147 feet above tide-level.

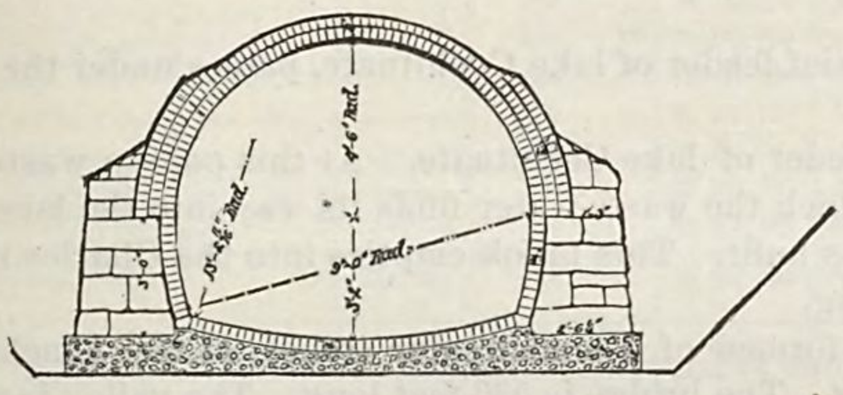
ADDITIONAL SUPPLY OF WATER.

The additional supply of water is derived from Sudbury river, a stream of moderate size, which flows in the towns of Westboro', Ashland, Framingham, Wayland, Sudbury, and Concord, in the state of Massachusetts. It flows in a general northeasterly direction, and meets, in the town of Concord, the Assabet river. Both streams then join to form the Concord river, which flows into the Merrimack river at Lowell.

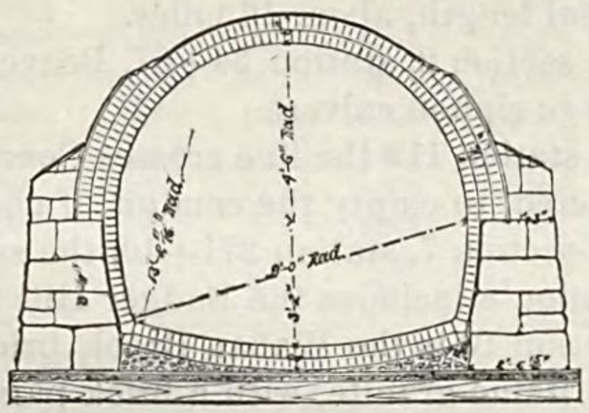
The city diverts the water from Sudbury river in the town of Framingham, at a point where the available water-shed is $74\frac{2}{3}$ square miles in area.

The calculations for the supply of the city are based upon an annual yield, in a dry year, of a quantity of water corresponding to a depth of 12 inches on the whole water-shed.

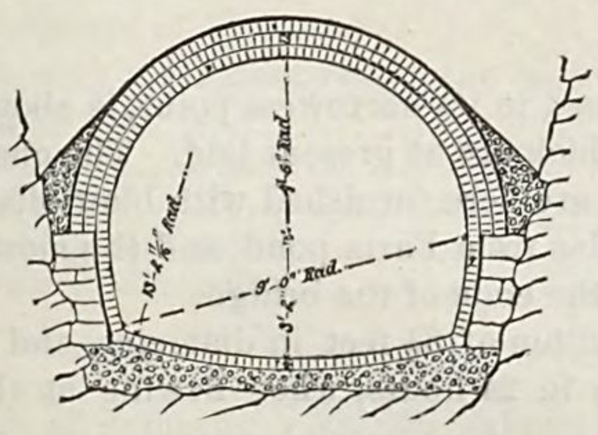
It has been calculated that seven reservoirs would be necessary, with a capacity of 4,900,000,000 gallons, to give to the city, in the driest year, a permanent supply of 40,000,000 gallons per day. Such an amount of water not being required at present, three reservoirs only, of a capacity of 2,000,000,000 gallons, are being constructed, which will be sufficient to secure to the city, in the driest weather, a supply of 20,000,000 gallons per day.



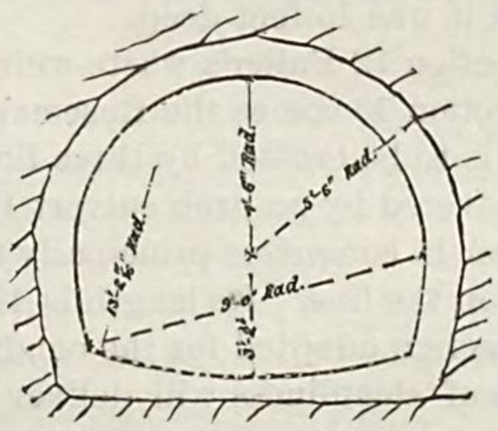
In Dry Excavation.



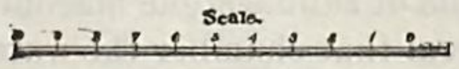
In Wet Excavation.



In Rock Excavation.



In Rock Tunnel.



SUDBURY RIVER CONDUIT.

From the lower reservoir on the river the water is conducted through a brick aqueduct into Farm pond, a natural pond of 200 acres, used as a settling reservoir. From Farm pond the water is drawn into the main conduit, 16 miles long, which carries it through the towns of Framingham, Sherborn, Natick, Needham, and Newton into Chestnut Hill reservoir. This reservoir, already described, receives the present supply from lake Cochituate, and is connected with the pipe distribution of the city.

The various parts of the work on the "additional supply" are either finished or in course of construction, and the water of Sudbury river is sent into the city. For description of the reservoirs and dams, see description of Boston water-works, above mentioned.

At the southeast corner of Farm pond is placed the gate-chamber, which contains the head of the main conduit. It is provided with two sets of large sluice-gates, 4 by 6 feet. Its foundation is on piles, as is the foundation of the beginning of the conduit in Farm pond. After leaving Farm pond the conduit passes to Chestnut Hill reservoir. Its total length is about 16 miles.

For convenience of description, reference will be made to the stations on the line enumerated in the following table. Stations are 100 feet in length:

Section.	Station.	To station.	Total length.
			Feet.
1	0	6	600
2	6	51+50	4,550
3	51+50	114+50	6,300
4	114+50	155+70	4,120
5	155+70	190	3,430
6	190	229	3,900
7	229	284+25	5,525
8	284+25	315+55	3,130
9	315+55	381	6,545
10	381	388	700
11	388	432	4,400
12	432	509	7,700
13	509	551+50	5,250
14	561+50	623	6,150
15	623	639	1,600
16	639	684	4,500
17	684	730	4,600
18	730	737	700
19	737	773+22	3,622
20	773+22	To end.	About 1 mile.

Total length, about 16 miles.

On section 2, station 34+67, Beaver Dam brook, the chief feeder of lake Cochituate, passes under the conduit by a large siphon culvert.

At station 112 the line crosses Course brook, another feeder of lake Cochituate. At this point a waste-weir is constructed, to empty the conduit, if necessary, and from which the waste-water finds its way into the lake.

On section 7, station 271+40, the second waste-weir was built. This brook empties into the Charles river.

Section 8 includes the Badger Hill tunnel, 1,575 feet long.

Section 10 is the Waban Brook bridge. The bridge is formed of 9 semicircular arches, 44 feet 8 inches span, built of Maine granite, with a brick parapet and iron railing. The bridge is 536 feet long. The valley is about 40 feet deep and 2,000 feet long. The line as located passes through a small knoll, and the conduit is carried over the remaining portion of the valley in an embankment, in section 11, 30 feet high and 1,200 feet long. The excavation on section 11 is largely in hard pan and rock. A cut in this section was at its deepest 35 feet, while 600 feet of it was 15 feet deep.

On section 12 Fuller's waste-weir is constructed.

On section 13 comes the Rosemary Brook siphon; the valley, crossed in its narrowest point, is about 1,800 feet wide. It is to be crossed by three lines of 48-inch pipe, only two of which are at present laid. The channel of the brook is covered by an arch culvert 10 feet in diameter, and the pipes are here furnished with blow-offs.

Section 15 comprises principally the Charles River bridge, 11.8 miles from Farm pond, and the most important structure on the line. Its length is 475 feet between the chambers at the ends of the bridge.

The section adopted for the conduit is equivalent to a circular section of 8½ feet in diameter, and in ordinary conditions of cleanliness will deliver at the rate of 70,000,000 gallons in 24 hours, when flowing at the assumed water-line.

Throughout the whole length of the conduit, manholes are provided, about 1,500 feet apart. The arch and interior lining are of brick, and the side-walls of rubble-stone masonry. The conduit terminates in a large chamber located at the Chestnut Hill reservoir. From that chamber the water from Sudbury river is distributed as follows, each pipe being provided with a sluice-gate: One 48-inch pipe is connected with one of the divisions of the Chestnut Hill reservoir, one 60-inch pipe is connected with the other division of the Chestnut Hill reservoir, one 48-inch pipe with the Cochituate aqueduct. Another 48-inch pipe is laid around the Chestnut Hill reservoir, and is connected, independently of it, with the city pipes. Room has also been provided for a duplicate of this pipe, which will be laid when the increase in the consumption of water shall render it necessary.

The report on the Boston water-works of 1874, already referred to, gives, in table 111, the amount of rainfall, consumption, etc., from 1852 to 1874.

The total cost of the works to May 1, 1880, is $16,341,908 for the Cochituate water-works and $1,614,648 for the Mystic works.

The expenses for maintenance and repairs of the Cochituate works for the year ending May 1, 1880, amounted to $171,160; of the Mystic works, $96,079. Total, $267,239.

The cost of the works for "additional supply", up to October 1, 1880, was $5,234,678, with land damages of $543,190.

The Roxbury high service comprises engine-house, 3 pumping-engines, force-main, stand-pipe, Parker Hill distributing reservoir, and distribution mains.

The engine-house, located on Elmwood street, is a plain brick building 40 feet wide, comprising, with the boiler-house and coal-shed, a space of 5,563 square feet. It contains two high-pressure, horizontal, direct-acting engines, built by the Boston Machine Company in 1870, and driving two double-acting pumps. Their capacity is 2,400,000 gallons per day each; diameter of pump-cylinders, 14 inches; diameter of steam-cylinders, 20 inches; stroke, 36 inches; diameter of fly-wheels, 15 feet; number of revolutions per minute, 25; duty, 30,000,000 foot-pounds. The steam-valves are double-seat puppet-valves, operated by four cams, connected by spur and bevel gearing with the main crank-shaft. The cost of the two engines, with boilers, is stated at $37,500.

Steam is supplied to each engine from a vertical multitubular boiler 7 feet in diameter and 13 feet high, with 2½-inch tubes, 10 feet long, at a pressure of 60 pounds per square inch. Their evaporative power is estimated at 11 pounds of water per pound of anthracite coal, and the details may be seen in the appended table for 1879:

1879.	ENGINE NO. 2.			WORTHINGTON ENGINE.			Total amount pumped by both engines.	Daily average amount pumped.	Total amount of coal consumed.	Daily average amount of coal consumed.	Ashes and clinkers.	Quantity pumped per pound of coal.	Average lift.	Duty per 100 pounds of total coal by Worthington engine.
	Total pumping time.		Total amount pumped.	Total pumping time.		Total amount pumped.								
	Hrs.	*Min.*	*Gallons.*	*Hrs.*	*Min.*	*Gallons.*	*Gallons.*	*Gallons.*	*Pounds.*	*Pounds.*	*Per cent.*	*Gallons.*	*Feet.*	*Ft. pounds.*
January	.....	.....	.....	651	.....	79,360,000	79,360,000	2,560,000	150,400	4,852	12.7	527.7	118.04	51,946,100
February	.....	.....	.....	588	.....	67,084,000	67,084,000	2,395,857	122,900	4,389	11.5	545.8	115.27	52,474,200
March	.....	.....	.....	651	.....	69,083,500	69,083,500	2,228,500	124,200	4,006	11.6	556.2	112.04	51,972,400
April	.....	.....	.....	633	.....	60,357,000	60,357,000	2,011,900	106,500	3,550	12.7	556.7	109.96	51,971,200
May	7	30	443,210	636	55	67,704,000	68,147,210	2,198,297	120,700	3,894	13.0	568.3	111.11	52,659,900
June	.....	.....	.....	630	.....	70,339,000	70,339,000	2,344,633	124,000	4,133	13.0	567.3	110.88	52,455,800
July	.....	.....	.....	644	52	69,409,000	69,409,000	2,239,000	128,690	4,151	15.1	539.5	113.65	51,122,800
August	.....	.....	.....	650	.....	72,044,000	72,044,000	2,324,000	133,900	4,319	14.7	538.0	116.89	52,450,000
September	.....	.....	.....	630	.....	66,371,000	66,371,000	2,212,367	126,100	4,203	15.3	526.3	117.35	51,511,600
October	.....	.....	.....	651	.....	66,185,000	66,185,000	2,135,000	121,700	3,926	14.3	543.8	116.66	52,910,100
November	.....	.....	.....	630	.....	63,550,000	63,550,000	2,118,333	118,800	3,960	13.1	534.9	116.19	51,837,700
December	.....	.....	.....	651	.....	68,897,500	68,897,500	2,222,500	132,700	4,281	13.4	519.2	118.04	51,113,000
Averages and totals	7	30	443,210	7,646	47	820,384,000	820,827,210	2,248,842	1,510,500	4,138	13.4	543.4	114.81	52,057,100

The capacity of these two engines combined is equivalent to about 4,800,000 gallons.

In 1877 a Worthington duplex engine was erected, of a capacity of 3,000,000 gallons per day, and since that time it has done most of the pumping with an economy shown by the following table. The stroke is 38 inches; diameter of steam-cylinders—high pressure, 21 inches, low pressure, 36 inches; diameter of pump-plungers, 17½ inches; number of strokes per minute, about 48. The boiler used is similar to those just described, but generates steam at a pressure of 35 pounds.

The following statement shows the cost of pumping:

Salaries	$3,743 96
Fuel	3,714 29
Repairs	2,206 60
Oil, waste, and packing	255 01
Gas and small supplies	358 80
Total	10,278 66

The cost of pumping 1,000,000 gallons 1 foot high in each year since the high-service works have been in operation is as follows:

1871	$0 37	1875	$0 22
1872	34	1876	18
1873	$28\frac{3}{10}$	1877	$13\frac{7}{10}$
1874	$24\frac{4}{10}$	1878	$12\frac{2}{10}$

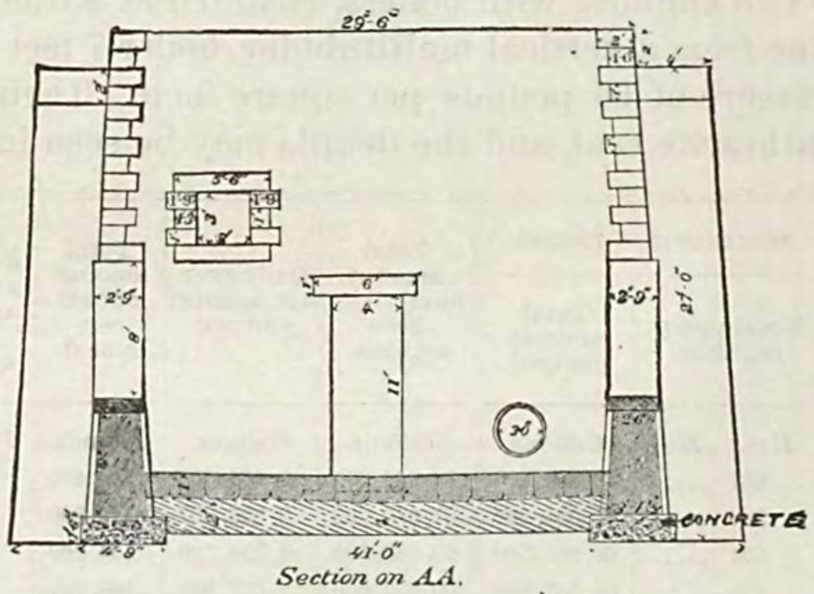
The supply to these pumps is through a 16-inch main connected with the Cochituate system under a head of 33 feet, and the average lift is 114 feet.

From the engines the 16-inch mains join and extend as a 16-inch main 2,500 feet to the stand-pipe, where the water can be diverted around the latter and direct into the mains if desired.

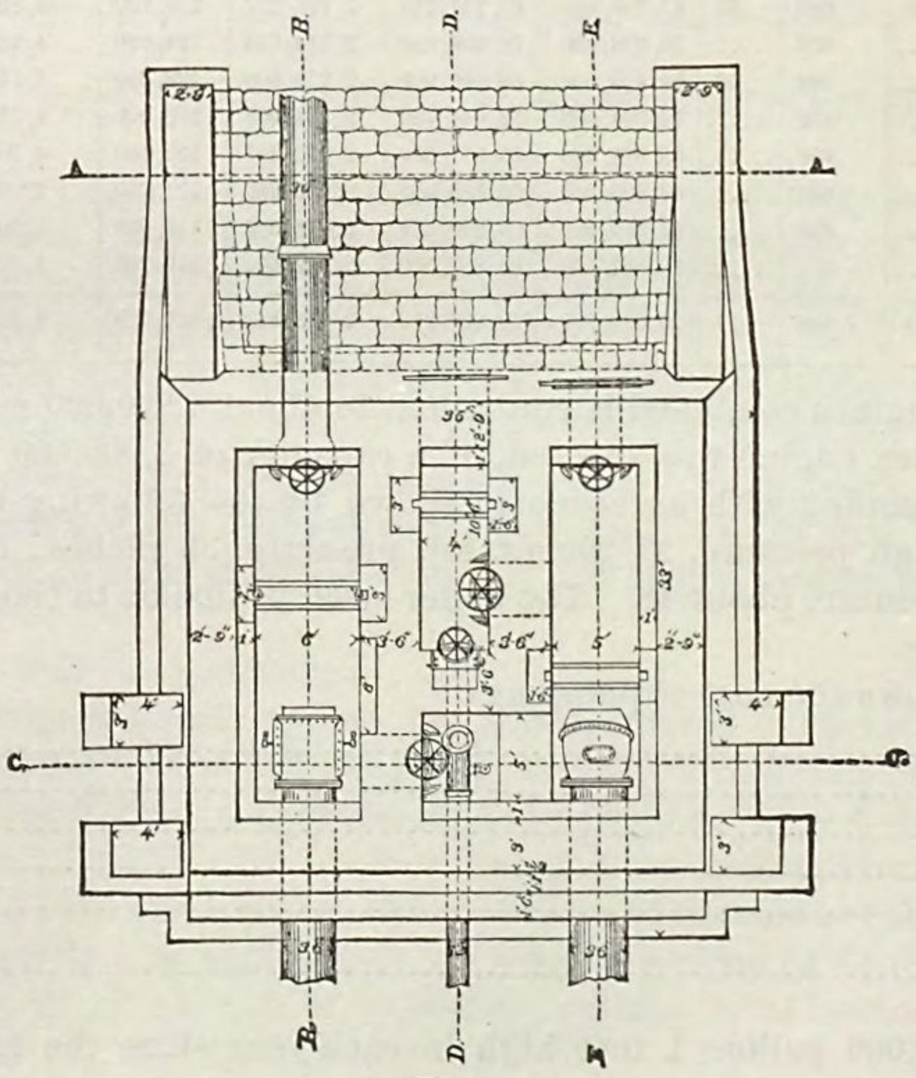
The stand-pipe is of boiler-iron, 5 feet in diameter and 80 feet high. A spiral staircase 3 feet wide extends to the summit, and the whole is inclosed in a brick tower, trimmed with granite and painted white, 15 feet in diameter at bottom and 13 feet at top.

THE PARKER HILL DISTRIBUTING RESERVOIR.

In case of accident to the pumps it was necessary to have a supply on hand, and hence the construction of this reservoir. From the 16-inch force-main near the stand-pipe a 24-inch branch is taken off leading to this reservoir. Its location is about 3 miles from the state-house. It is nearly rectangular in plan, 290 feet at the north and south sides, 196 feet at the east, and 253 feet on the west ends at the level of the top of the banks. The latter slope 1½ to 1 inside and 1¾ to 1 outside; capacity, 7,200,000 gallons; area of high-water surface, 1.47 acre; depth, 22 feet at sides and 24 feet at center. It was built on a soil composed of a hard clay; gravel and 2 feet of clay puddle were spread upon it. The banks were lined with the same, upon which were laid 8 inches of broken stone and a paving 16 inches thick of stone, the surface of which is pointed in cement. The width of banks is 22 feet, and they are finished off with a flagged walk 5 feet wide.



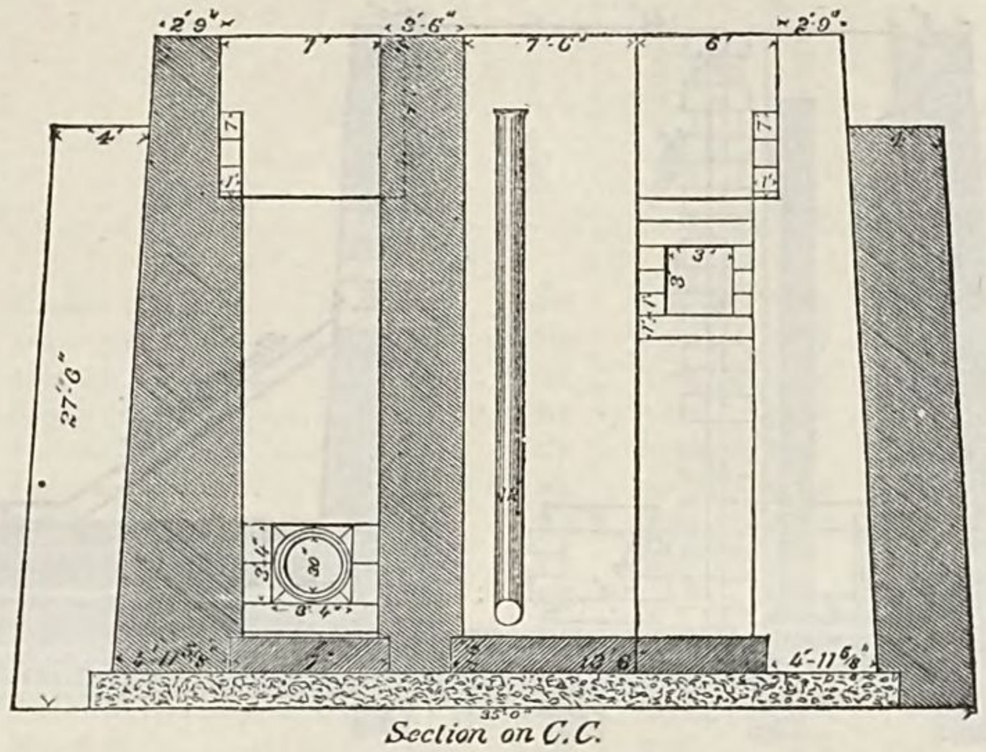
Section on AA.



Plan

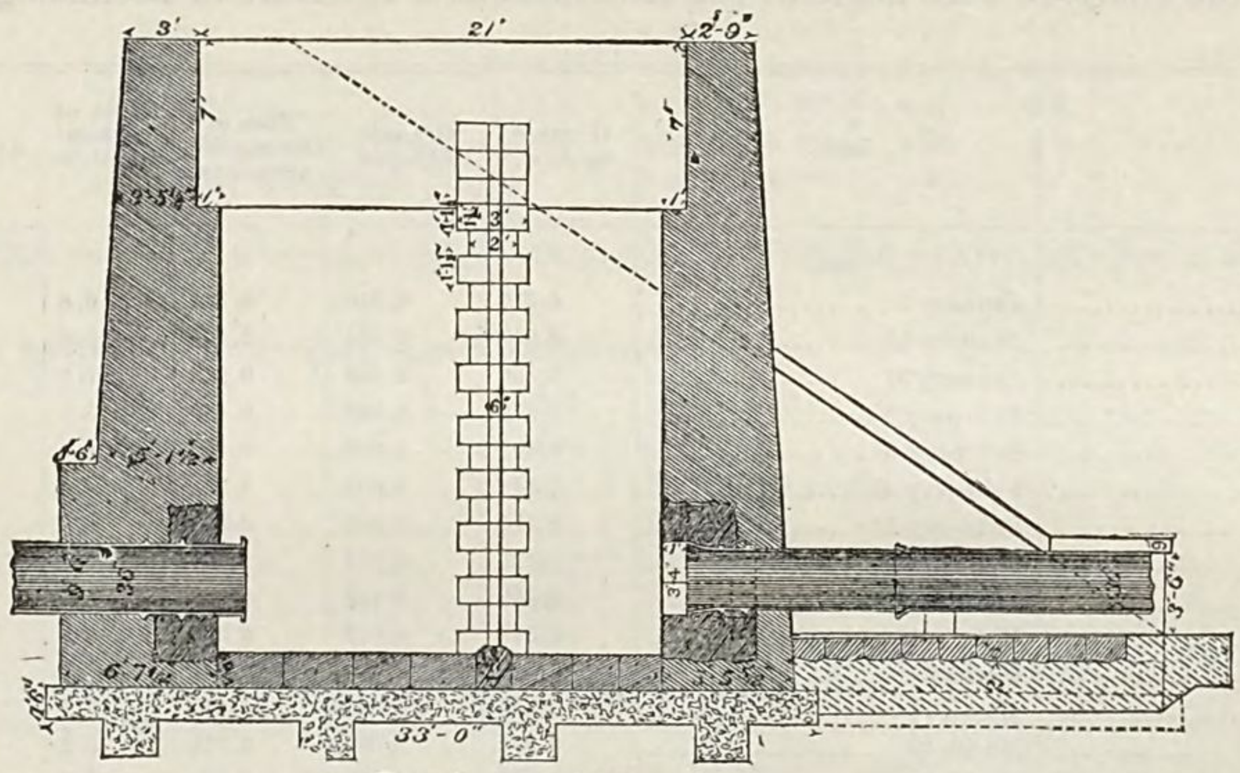
The gate-house is nearly in the center of the southerly side, and is shown in the cut, together with details and dimensions. The most westerly chamber is the inlet, 6 by 19 feet. A float attached to the inlet-pipe (36 inches in diameter) regulates automatically the height of the water. Between the float and the reservoir side of the chamber is a set of grooves, 6 inches wide, for stop-planks. The discharge-pipe, 30 inches in diameter, leaves this inlet-chamber and continues to the center of the reservoir, where it discharges upon a stone apron. It is partly shown in plan.

The outlet-chamber is 6 by 21 feet at the floor-level. The 36-inch outlet pipe is near the bottom. A 12-inch iron drain-pipe passes through this chamber. It is provided with two small iron gates to drain the chambers. It rises vertically to high-water mark, is open at top, and 23 feet above the paving of the floor of the chamber. One

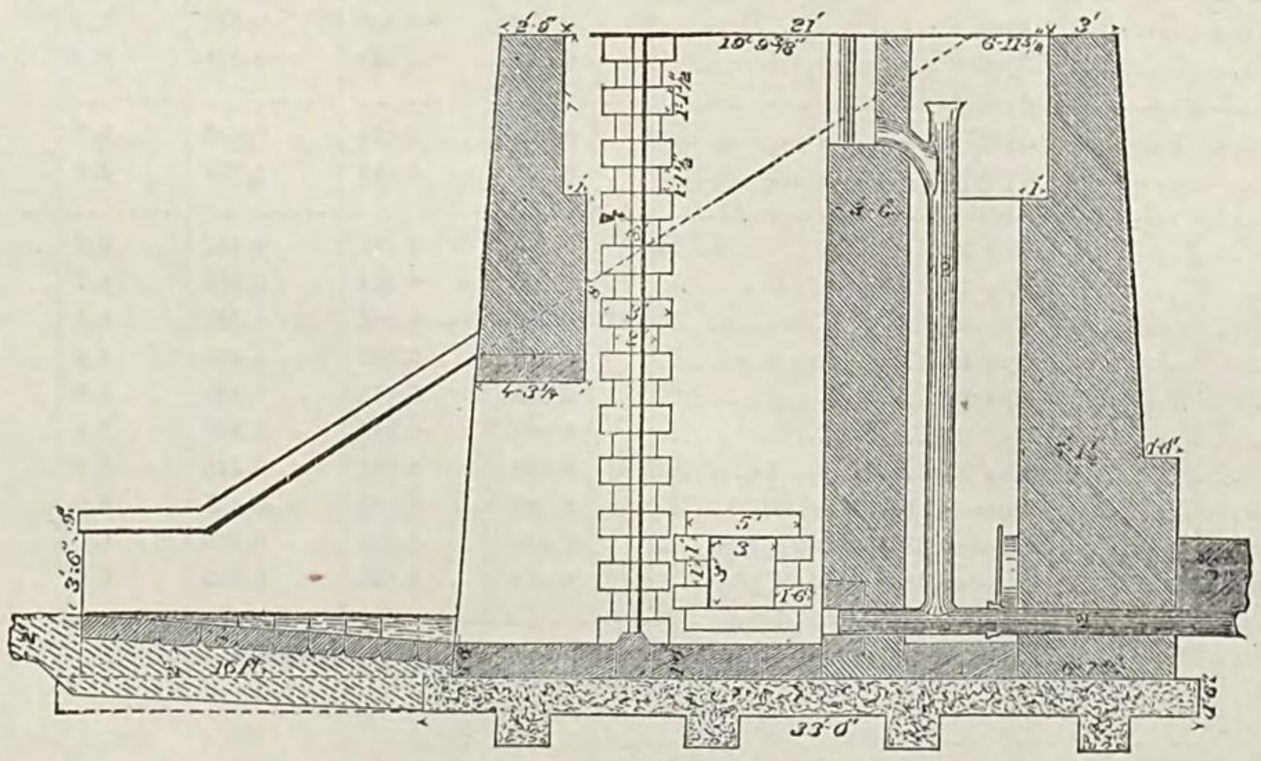


Section on C.C.

gate, 3 feet square, opens from the reservoir to the outlet-chamber at a height of 14 feet above the bottom. Another 3 feet square and 18 inches above the botton connects this chamber with the drain-chamber.



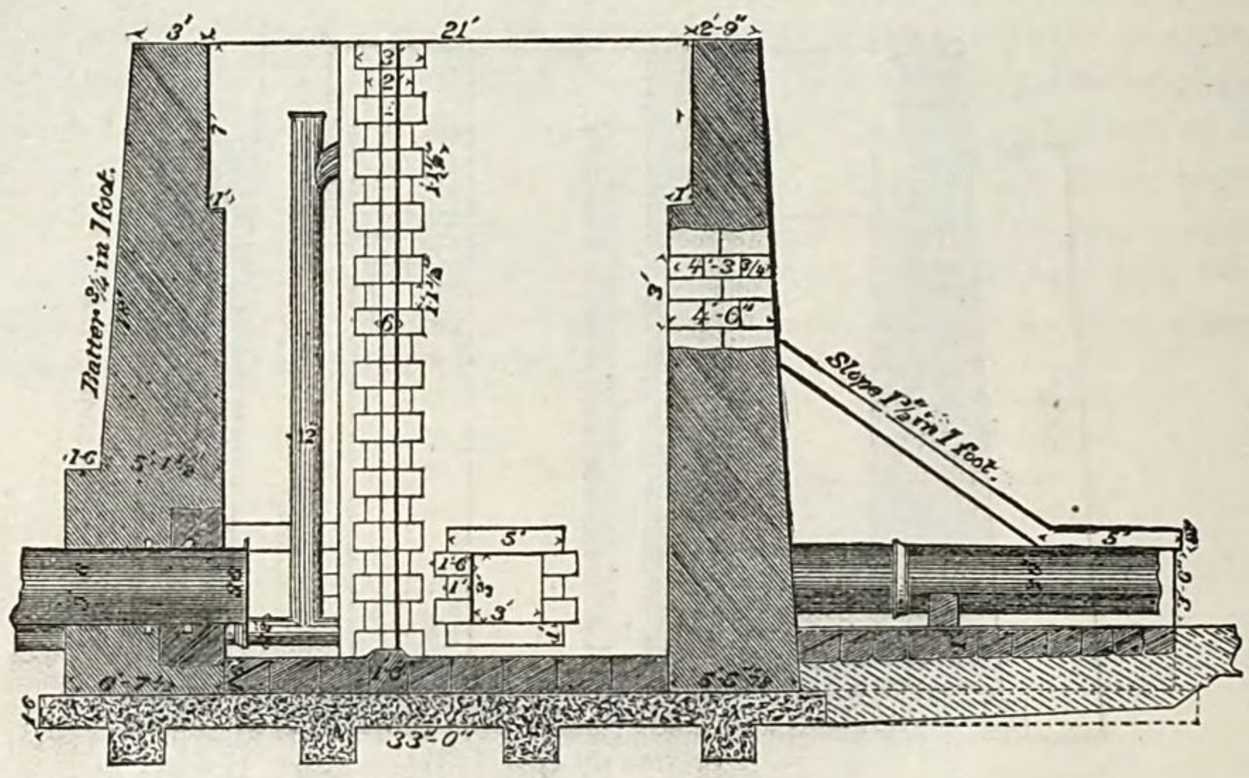
Section on B.B.



Section on D.D.

It may be well to explain that the gate-house is divided below the floor-level into the three chambers mentioned, viz. outlet-, inlet-, and drain-chambers. The last-named is 4 by 11½ feet at floor-level, has a rectangular opening into

the reservoir 4 by 11 feet, the bottom of which is on a level with the bottom of the chamber. The cuts in section show BB as the inlet-, DD the outlet-, and EE the drain-chamber. The cost of the reservoir, exclusive of land damages, was $141,317.



Section on E.E.

The analyses of the waters from the Mystic works are appended. The samples were drawn from the service-mains in each case, and the analyses were made at the Massachusetts Institute of Technology:

Locality.	Date.	Organic carbon.	Organic nitrogen.	Sum of the organic elements.	Ratio of carbon to nitrogen.	Ammonia.	"Albuminoid ammonia."	Total solids.
	1880.							
Charlestown	January 1	0.315	0.046	0.361	6.8	0.012	0.013	9.9
Do	January 15	0.313	0.054	0.367	5.8	0.012	0.011	10.2
Mystic pond	January 30	0.335	0.043	0.378	7.8	0.053	0.019	10.9
Charlestown	February 5	0.375	0.066	0.441	5.7	0.025	0.018	11.0
Mystic pond	February 6	0.401	0.095	0.496	4.0	0.040	0.023	11.4
Charlestown	February 12	0.442	0.060	0.502	7.4	0.037	0.018	11.4
Mystic pond	February 17	0.471	0.057	0.528	8.3	0.025	0.021	8.8
Charlestown	February 19	0.421	0.044	0.465	9.6	0.035	0.020	10.1
Do	February 26	0.346	0.039	0.385	8.9	0.031	0.016	10.4
Do	March 4	0.347	0.039	0.386	8.9	0.033	0.016	9.9
Mystic pond	March 6	0.349	0.040	0.389	8.7	0.044	0.017	10.3
Charlestown	March 11	0.356	0.062	0.418	5.7	0.027	0.016	9.7
Do	March 19	0.314	0.060	0.374	5.3	0.027	0.013	9.9
Do	March 25	0.322	0.062	0.384	5.2	0.027	0.015	10.4
Do	April 1	0.309	0.045	0.354	6.9	.....	.....	10.3
Mystic pond	April 5	0.273	0.046	0.319	5.9	0.040	0.016	10.1
Charlestown	April 9	0.297	0.044	0.341	6.8	0.024	0.015	10.7
Mystic pond	April 14	.....	.....	.....	.....	0.041	0.017	10.2
Charlestown	April 15	0.361	0.054	0.415	6.7	0.020	0.017	10.5
Do	April 22	0.297	0.060	0.357	4.9	0.013	0.016	10.8
Do	April 29	.....	.....	.....	.....	.....	.....	10.4
Mystic pond	May 3	0.386	0.061	0.447	6.3	0.037	0.020	10.2
Charlestown	May 6	0.256	0.054	0.310	4.7	0.007	0.017	10.7
Mystic pond	May 12	0.366	0.082	0.448	4.4	0.031	0.021	10.5
Charlestown	May 13	0.333	0.068	0.401	4.9	0.008	0.016	10.9
Do	May 20	0.359	0.073	0.432	4.9	0.008	0.016	10.5
Mystic pond	May 24	0.332	0.045	0.377	7.4	0.031	0.021	10.6
Charlestown	May 27	0.358	0.061	0.419	5.9	0.009	0.021	10.8
Charlestown, mean of 35–39 samples	June, 1879, to May, 1880	0.392	0.065	0.457	6.0	0.012	0.018	9.9
Mystic pond (surface), mean of 12–14 samples	October, 1879, to May, 1880	0.349	0.054	0.403	6.5	0.028	0.018	10.0
Charlestown, mean of 19–20 samples (*a*)	October, 1879, to May, 1880	0.339	0.053	0.392	6.6	0.019	0.015	9.8

a This average is made up from the samples drawn in Charlestown.

The analyses of the Boston water by the same authority were made of water drawn from the service-pipe in the Institute of Technology, as follows:

Date.	Temperature in centigrade degrees.	Organic carbon.	Organic nitrogen.	Sum of the organic elements.	Ratio of carbon to nitrogen.
1880.					
January 1	3.3	0.500	0.055	0.555	9.0
January 16	3.3	0.545	0.064	0.609	8.5
January 23	.....	0.694	0.064	0.758	10.8
January 31	3.6	0.614	0.041	0.655	15.0
February 5	2.9	0.659	0.061	0.720	10.8
February 9	4.0	0.668	0.072	0.740	9.3
February 12	.....	0.723	0.063	0.786	11.5
February 19	3.0	0.592	0.051	0.643	11.6
February 25	3.1	0.526	0.064	0.590	8.2
March 4	6.3	0.582	0.047	0.629	12.4
March 11	4.2	0.443	0.071	0.514	6.2
March 18	6.8	0.413	0.060	0.473	6.9
March 26	4.2	0.438	0.037	0.475	11.8
April 1	4.8	0.368	0.046	0.414	7.9
April 9	.....	0.446	0.048	0.494	9.3
April 16	9.2	0.397	0.044	0.441	9.0
April 22	9.8	0.360	0.047	0.407	7.7
May 6	13.2	0.325	0.046	0.371	7.1
May 13	15.6	0.361	0.063	0.424	5.7
May 21	15.8	0.423	0.034	0.457	12.4
May 28	18.8	0.447	0.075	0.522	6.0
Mean of 42 samples	.....	0.452	0.051	0.503	8.9

The daily consumption for 1880 averaged 26,500,000 gallons, and frequently reached a maximum of 40,000,000 gallons.

The total number of hydrants is divided about as follows:

Boston	1,325	Deer island	16
South Boston	486	Brookline	8
East Boston	297	Charlestown	3
Boston Highlands	788	Chelsea	8
Dorchester	683		
West Roxbury	323	Total	4,144
Brighton	207		

The following table gives the total length of mains laid to May, 1880:

	DIAMETER OF PIPES IN INCHES.															Aggregate.
	60	48	40	36	30	24	20	16	12	10	9	8	6	4	3	
Feet of pipe laid in Brookline, Boston Highlands, and Boston proper	....	7,283	23,166	20,070	26,770	5,773	5,823	20,160	116,721	.....	655	33,880	324,781	94,605	.....	
Number of stop-cocks in same	...	6	6	8	11	11	9	45	254	.....	.....	105	877	416	.....	
Feet of pipe laid in Boston Highlands	....	.....	.....	185	109	11,427	6,200	12,130	87,226	.....	916	7,167	164,706	29,314	238	
Number of stop-cocks in same	....	.....	.....	1	2	9	4	21	130	.....	.....	15	361	129	2	
Feet of pipe laid in South Boston	....	.....	.....	.....	.....	.....	13,206	.....	47,564	.....	105	5,156	129,331	37,170	.....	
Number of stop-cocks in same	....	.....	.....	.....	.....	.....	6	.....	77	.....	.....	9	248	112	.....	
Feet of pipe laid in East Boston	....	.....	.....	.....	.....	1,463	15,972	2,152	36,715	9,923	218	23,074	86,841	6,511	.....	
Number of stop-cocks in same	....	.....	.....	.....	.....	.....	8	5	45	3	.....	15	154	55	.....	
Feet of pipe laid in Dorchester	....	.....	.....	.....	.....	7,784	3,698	456	105,970	.....	1,340	27,752	119,416	4,331	.....	
Number of stop-cocks in same	....	.....	.....	.....	.....	5	2	1	125	.....	.....	42	237	26	....	
Feet of pipe laid in West Roxbury	....	.....	.....	.....	.....	.....	10	2,916	72,199	.....	.....	37,318	47,275	1,452	.....	
Number of stop-cocks in same	....	.....	.....	.....	.....	.....	.....	1	69	.....	.....	45	95	14	.....	
Feet of pipe laid in Brighton	....	.....	.....	.....	.....	.....	.....	8,975	42,697	.....	.....	21,772	22,173	520	.....	
Number of stop-cocks in same	....	.....	.....	.....	.....	.....	.....	5	58	.....	.....	32	52	3	.....	
Feet of pipe laid in Newton, Needham, and Chestnut Hill reservoir, Framingham	266	16,051	1,435	1,111	2,140	.....	.....	20	2,043	.....	.....	.....	360	.....	.....	
Number of stop-cocks in same	....	.....	.....	2	.....	.....	.....	2	4	.....	.....	.....	2	.....	.....	
Total length of pipe laid, in feet	266	23,334	24,601	21,366	21,019	26,447	44,909	46,809	511,165	9,923	3,234	156,119	894,883	173,903	238	1,966,216
Number of stop-cocks put in	....	6	6	11	13	25	29	80	762	3	.....	263	2,026	755	2	3,981

The water-works of Boston are under the control of the present city engineer, Henry M. Wightman, and W. E. Swan, clerk of the board.

HARTFORD, CONNECTICUT.

Hartford contains a population of 42,015 inhabitants, and is situated on the Connecticut river, about 40 miles, in a direct line from Long Island sound. Its business interests are largely mercantile and manufacturing. It is situated upon a succession of ridges of land running north and south. The first of these ridges rises from the river for a distance of a few blocks to the principal street, and thence it falls for several blocks to the tracks of the New York, New Haven, and Hartford railroad; crossing these, the land again rises rather sharply toward the west, forming Asylum hill, upon which the distributing reservoir is located. The ridges mentioned are also intersected in the southern portion of the city by a narrow strip of lower land.

Water was first introduced into the city in 1855, and is owned and managed by the city. The largest part of the supply is derived by gravity from a number of small streams in West Hartford and Farmington, about 5 miles west of the city, known by such names as Trout brook, Mine brook, Cadwell brook, etc., having a total drainage area of about 9.58 square miles, and situated among the hills at an elevation above the Connecticut river of 260 feet to the level of high water in the first or oldest reservoir. In addition to this gravity supply there is an auxiliary supply from the Connecticut river to certain portions of the city during dry weather, by pumping machinery on the west bank of the river in the upper part of the city. The pumping is direct into the mains, and a pressure is produced equivalent to 125 feet head.

In 1866 the pumping-works which furnished the original supply were supplemented by an additional supply from the first new reservoir on Trout brook, in West Hartford, which had been begun in 1865, and completed at a cost of about $200,000, including supply-pipe, damages, etc.

This reservoir, located on Trout brook, and known as No. 1, as detailed by the commissioners in 1867, flows, when full, 32 acres, and has a capacity of 156,600,000 gallons. The dam has a total height of 53 feet, rising 6.3 feet above the top of the water, and is 782 feet long. As already stated, the high-water surface is 260 feet above mean high water in the Connecticut river. The dam is 27 feet wide at the top; slope, 3 to 1 on the inside and 2 to 1 on the outside. A puddle-wall extends from 3 feet above high-water mark, where it is 4 feet thick, downward through the center of the dam to the base, where it is bedded in the rock and is 25 feet thick. Three 20-inch mains, one as a waste-pipe, pass through the base of the dam. It was partially destroyed by a freshet. The above is the condition now existing. It was planned by William J. McAlpine, civil engineer. The waste-weir is 42 feet long.

Reservoir No. 3 is located on Mine brook, and about one-tenth of a mile north of No. 1. It flows an area of 44 acres, has a capacity of 283,694,375 gallons, and was built in 1868. The dam is built upon a foundation of rock, and is constructed of earth, with a puddle-wall similar to that of No. 1. Its width at top is 27 feet, and its total length 1,300 feet. It extends 5 feet above high-water line, has an interior slope of 3 to 1, covered with a wall of riprap. The exterior slope is 2 to 1, and the extreme height of the dam is 42 feet. The maximum depth of water is 33 feet. One 20-inch and one 16-inch pipe are laid through the base of the dam. This reservoir, though called No. 3, was the second one built. Its waste-weir is 56 feet in length.

The storage capacity of these two reservoirs being insufficient for the purposes of the city, a third one was built, and completed in 1875, known as No. 4. It is located about 1 mile northwest of No. 1, on a branch of Trout brook, in a valley bordered by considerable hills of trap-rock, and on cleared and grubbed woodland. As described in the reports of the commissioners, the following dimensions, etc., are given:

The bottom trench was cut 25 feet in width to rock, at a depth of 19 feet below the bed of the stream. Above this the earth dam was built to a height of 42½ feet above the bed of the stream, with a core of puddle, as in the other two already described. The length at the bottom is 170 feet, at the top 560 feet. Extreme width at the base, 225 feet; at the top, 30 feet, and at high-water line, 50 feet. The dam rises 5 feet 6 inches above high-water line. The interior slopes 3 to 1, the exterior 2 to 1, with a riprap facing 30 inches deep, of stone.

A waste-way 25 feet wide was constructed about 700 feet above the dam on the eastern shore, and passes around the end at a distance of about 100 feet from it, discharging into the stream 300 feet below the dam. Two discharge-pipes are built through the base at the former level of the stream—one 20 inches and the other 16 inches in diameter, both laid in a puddle-wall and protected by screens. A dike 310 feet long by about 5 feet deep has been built at the northern end of the reservoir to prevent the escape of water into Mine brook. Another dike 125 feet long by 4 feet deep prevents escape into the southerly section of reservoir No. 3, which is 6 feet below it in level. A 12-inch pipe connects reservoirs 3 and 4. These dikes have a facing of riprap as in the main dam.

The area of land overflowed by the reservoir at high water is 25.42 acres, and contains at that stage about 154,524,800 gallons. The whole cost of construction was $59,117. Average length 2,890 feet, and average width 380 feet.

Reservoir No. 2 has never been completed, but is described in the report of 1880.

The distributing reservoir is situated on Asylum hill, in the western portion of the town. It is an earth-embankment reservoir, 380 feet long by 180 feet wide at the level of the top of banks, and 360 by 168 feet at water-line. The total depth to high-water surface is 30 feet.

The embankments have a puddle-wall running through the center, the dimensions of which can not now be ascertained, as no drawings exist. The slope of the banks is 1 to 1 inside and 1½ to 1 outside. The inner face is riprapped with stone laid dry. The total capacity is 10,000,000 gallons.

The gate-house surmounts a chamber containing two compartments, and is 20½ by 22 feet. There are two supply-mains and one force main, and an 8-inch waste-pipe from the chambers. The force-main is 16 inches, one supply-pipe is 12 inches, and the other 8 inches in diameter. This reservoir is gradually falling into disuse. In April, 1879, the east and west banks gave way, emptying the basin and permanently weakening the banks, since which time but 25 feet of water has been retained in it, solely to prevent internal collapse. The slope of the inner face had evidently been made too abrupt for the materials used.

In addition to the gravity system already described, the pumping-machinery is employed as auxiliary during the summer months, and for a short time in the winter when the supply is short and consumption at its maximum. It consists of a beam-engine of the ordinary river-steamboat type, driving, by means of gear-wheels, a set of four plunger pumps, forcing the water directly into the mains. It was constructed by Messrs. Woodruff & Beach, of the Hartford Machine Company, in 1873. One set of machinery erected in 1855 had been removed. The engine is condensing; cylinder, 34 inches diameter; stroke, 5 feet; is run at about 40 revolutions per minute. The puppet-valves are operated by a cam-shaft with plug-rods, and a Wright's cut-off is employed.

The condenser is of the jet type. Air-pump, 21 inches diameter by 2 feet 10 inches stroke. The cost of the engines and pumps together is said to have been $18,244. The steam is supplied by one drop-flue boiler, with two tubes of about 16 inches diameter. It is 8 feet 7 inches in diameter by 22 feet long. The usual pressure is about 20 pounds, with a consumption of 4 tons of anthracite per 24 hours, and pumping about 3,500,000 gallons.

The pumps are four in number, located at the bottom of a deep well at one side of the engine, and operated by a system of gearing. They are plain plunger-pumps, with a diameter of plunger of 22 inches and stroke of 4 feet. The average speed when in use is about 10 (double) strokes ordinarily, and from 12 to 18 per minute in case of fire. The force-main directly connected with these pumps is 16 inches diameter, and the head maintained is about 122 feet at the pump-house. The valves in the pump-cylinders are rubber-faced wood-seated puppet-valves, with a lift of about 2 inches, diameter unknown. These pumps were guaranteed to pump 4,500,000 gallons per 24 hours, but are not employed at more than 3½ million. No duty-trial of the engines has ever been made.

In the construction of the Hartford water-works the cost has been appropriated to the various departments as follows:

Expenditures.	Pumping-engine.	Engine-house, lot, inlet, pier, etc.	Storage-lot, reservoir lot and gate-house.	Distribution hydrants and gates.	Service-pipe.	New works at West Hartford and Farmington.	Total.
To March 1, 1857	$18,244 75	$56,047 95	$74,845 43	$182,610 75	$5,198 91	.....	$336,947 79
In 1857	.....	25 25	.....	23,410 69	3,695 07	.....	27,131 01
In 1858	.....	78 69	.....	3,646 68	2,545 92	.....	6,271 29
In 1859	.....	1,213 81	23 34	6,250 15	2,328 11	.....	9,815 41
In 1860	.....	355 79	.....	5,292 21	2,847 93	.....	8,495 93
In 1861	.....	66 04	641 00	8,098 63	1,439 23	.....	10,244 90
In 1862	.....	.....	.....	8,228 76	2,224 15	.....	10,452 91
In 1863	.....	.....	.....	12,347 05	2,129 63	.....	14,476 68
In 1864	.....	.....	.....	5,937 30	3,127 38	.....	9,064 68
In 1865	.....	.....	.....	1,663 65	1,622 19	.....	3,285 84
In 1866	.....	.....	.....	34,158 82	2,149 07	$205,542 52	241,850 41
In 1867	.....	.....	.....	13,221 82	2,093 44	72,928 91	88,244 17
In 1868	.....	.....	.....	13,140 34	4,592 21	86,449 41	104,181 96
In 1869	.....	.....	.....	13,222 87	3,597 46	27,461 42	44,281 75
In 1870	.....	.....	.....	26,665 06	4,776 71	13,113 64	44,555 41
In 1871	.....	.....	8,000 00	30,528 68	4,852 14	200 00	43,580 82
In 1872	2,880 00	.....	.....	36,229 83	5,338 45	496 79	44,945 07
In 1873	9,600 21	.....	1,115 50	53,770 22	4,810 61	9,825 59	79,122 13
In 1874	.....	.....	.....	21,501 80	4,806 59	111,685 20	137,993 59
In 1875	.....	.....	.....	16,706 65	3,898 54	57,371 80	77,976 99
In 1876	.....	.....	.....	13,141 23	2,134 99	7,629 04	22,905 26
In 1877	.....	.....	.....	7,761 34	1,372 77	862 10	9,996 21
In 1878	.....	.....	.....	1,875 68	1,694 87	11,544 94	15,115 49
In 1879	.....	.....	.....	2,718 36	1,629 33	84,124 86	88,472 55
Total	30,724 96	57,787 53	84,625 27	560,128 57	74,905 70	687,236 22	1,495,408 25

The main conduit from the West Hartford reservoir consists of 51,896 feet of 20-inch pipe, laid in two parallel lines, one being cement-lined wrought iron and the other cast iron.

The distribution is carried out by pipes of the same character as the conduit, of diameters 3, 4, 6, 8, 10, 12, 16, 20, and 24 inches, the different lengths of which are:

	Feet.
3-inch	2,255
4-inch	44,171
6-inch	216,487
8-inch	21,796
10-inch	4,463
12-inch	9,690
16-inch	18,782
20-inch	51,896
24-inch	140
Total	369,680

The total length of pipe laid is $70\frac{3080}{5280}$ miles, divided as follows: $54\frac{4637}{5280}$ miles of cast-iron and $15\frac{3723}{5280}$ miles of wrought-iron and cement pipe.

The consumption amounts to about 5,000,000 per 24 hours, and the number of water-takers is about 5,000.

The annual expense of maintenance and repairs for 1879 was as follows:

Interest on bonds	$62,120
Repairs	17,481
Current expenses	13,513
Total	93,114

The total number of gates in use is 575, and of hydrants 362, Holyoke patent post.

The purity of the water may be judged from the following analysis by Professor B. Silliman in 1861:

No. 1.—*From Connecticut river:*

Solids	grains per imperial gallon	3.07
Organic matter	do	1.26
Inorganic matter	do	1.81
Carbonate of lime	do	0.01
Hardness	degrees	1.64

No. 2.—*From Trout brook:*

Solids	grains per imperial gallon	3.91
Organic matter	do	1.95
Inorganic matter	do	1.95
Carbonate of lime	do	$0.01\frac{7}{10}$
Hardness	degrees	1.19

The works are at present under the charge of Mr. Edward J. Murphy, president and superintendent.

SPRINGFIELD, MASSACHUSETTS.

Springfield, containing a population of 33,340, is situated on the east bank of the Connecticut river, 26 miles north of Hartford, Connecticut. It is pre-eminently a city of manufactures. One portion of the city is in a low level area and the other on an elevated plateau. The plan of the streets is regular and rectangular.

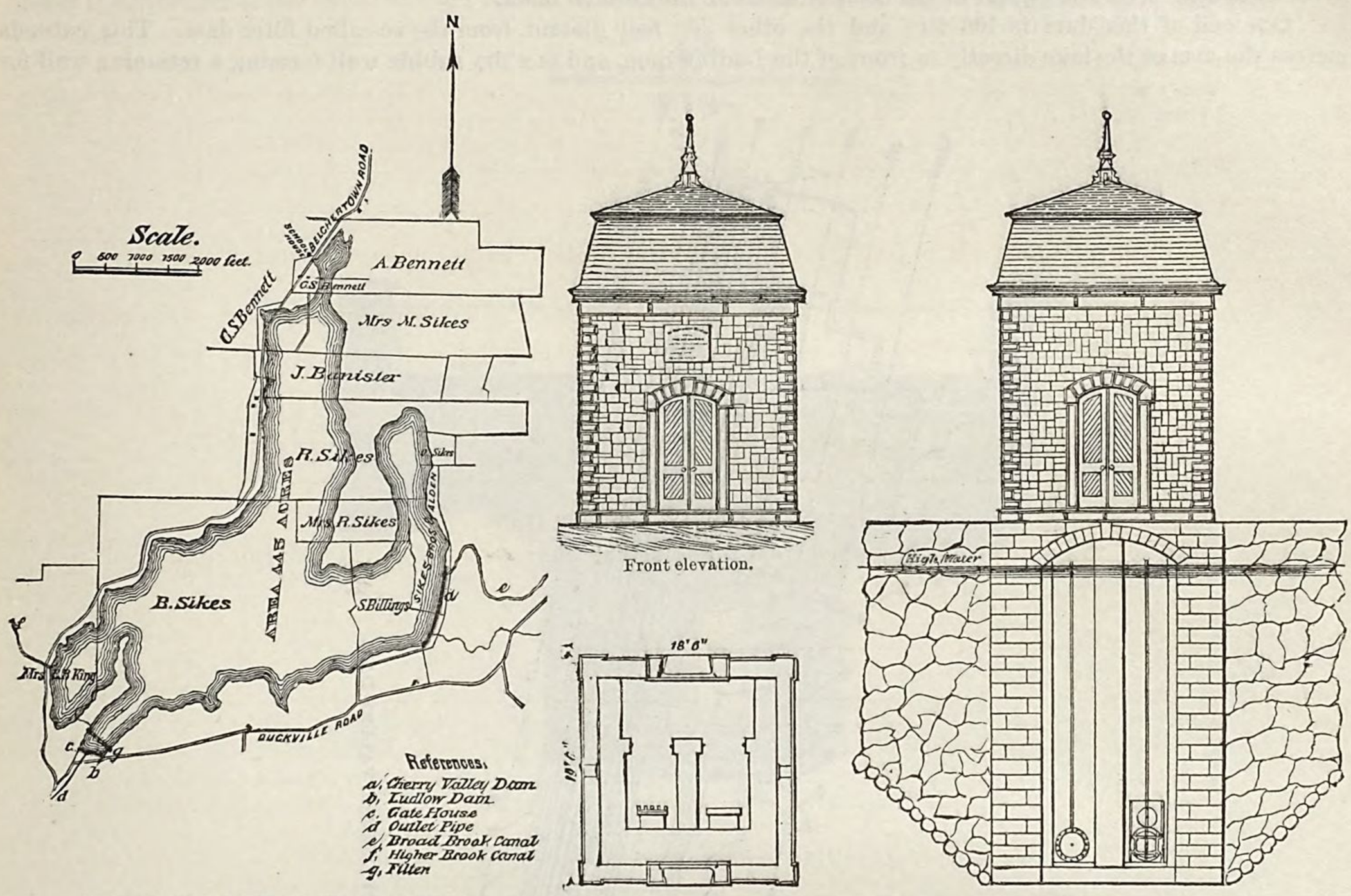
The water-supply was first furnished to the city in 1840 by a private corporation, whose property was bought and enlarged in 1874 by the city. The system is by gravity from three artificial reservoirs, one located 10 miles east from the city and two within the city limits. The former, known as the "Ludlow reservoir", supplies the high-service mains, and the latter, known by the names of "Lombard" and "Van Horn", at a less elevation, supply the low service.

The former (Ludlow) reservoir was added to the system in 1874, and drains an area of about 3 square miles. The soil overflowed by the reservoir was chiefly sand and gravel, with a small area of marsh and 281 acres of woodland, the rest having been under cultivation. The maximum elevation or head of water above the main street is 312 feet. The average annual rainfall in Springfield for 25 years is 45.33 inches.

The area of the Ludlow Reservoir water-surface is 445 acres, and its shape is shown in the accompanying map. The marshy portions were sanded over to a depth of 18 inches, and the part included between the Ludlow dam and the filtering dam, an area of $3\frac{3}{4}$ acres, was covered with sand to a depth of 2 feet.

Two dams retain the waters of the different streams and form the reservoir. One of these is known as the Cherry Valley dam, and the other and smaller one as the Ludlow dam. The total capacity is 2,000,000,000 gallons. The latter is shown in section in the drawing on page 36. The whole front of the dam, from the gate or toe of the slope to the back of the priming-wall, was built upon a hard-pan foundation, and the base of the wall is sunk 3 feet into this foundation. This priming-wall is 18 inches thick, of stone in cement, and extends to within 2 feet of the top of the embankment, the top being covered with a rubble-wall 2 feet by 18 inches throughout the whole length of the dam. The dam is 2,352 feet long, 1,021 feet of it being only from 3 to 5 feet high, and of a total height of 39

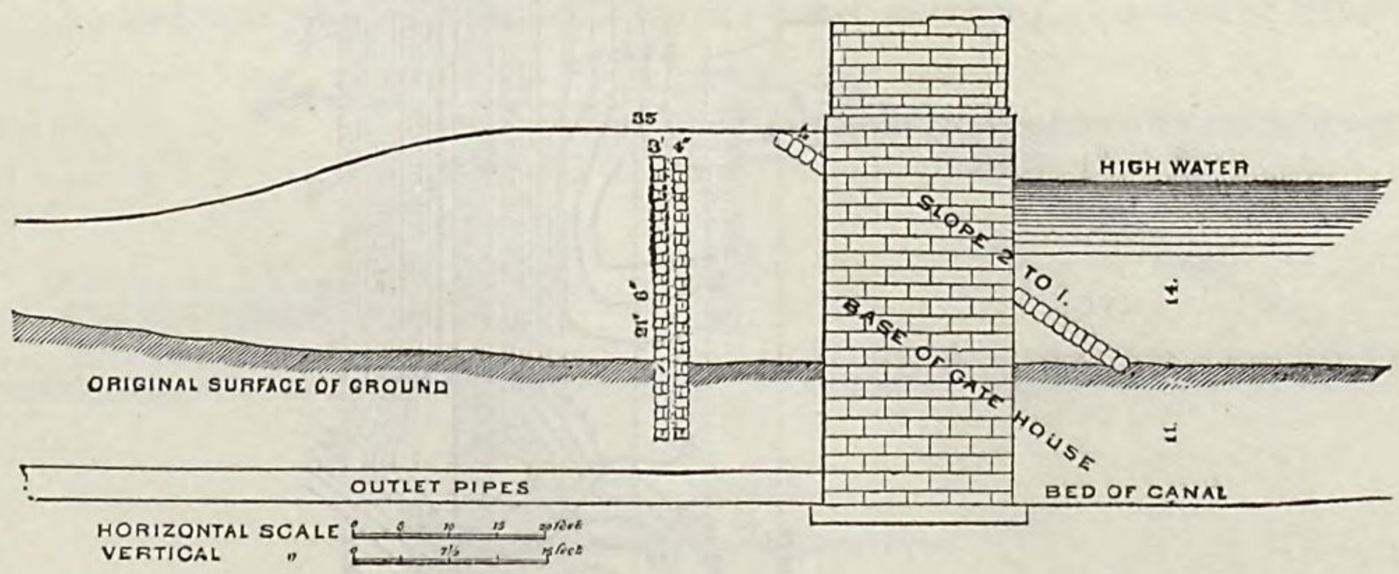
feet. The length of the priming-wall is 1,297 feet. Height of top of bank above top of water, 4 feet. A roll-way or waste-weir, 34 feet long, paved with stone and resting upon a ledge, discharges the waste water. The width of embankment at the top is 25 feet, with a slope of 2 to 1 inside and out. The whole of the filling is puddled earth, and is faced with a granite riprap 12 or 24 inches thick. Through the base of the dam extends a waste-pipe 20



MAP OF THE CHERRY HILL RESERVOIR.

inches in diameter, surrounded by stone masonry for its entire length and provided with a gate at each end, the upper one being inclined at the angle of the inner slope, and operated from the top of the dam by a rod. A dry-stone drain, filled with loose stone, and 5 feet square, extends along the whole lower toe of the dam.

The Ludlow dam, the position of which is shown on the plan of the lake, is somewhat similar in construction to the Cherry Valley dam, being an earth puddle embankment with a masonry priming-wall of 3 feet 4 inches

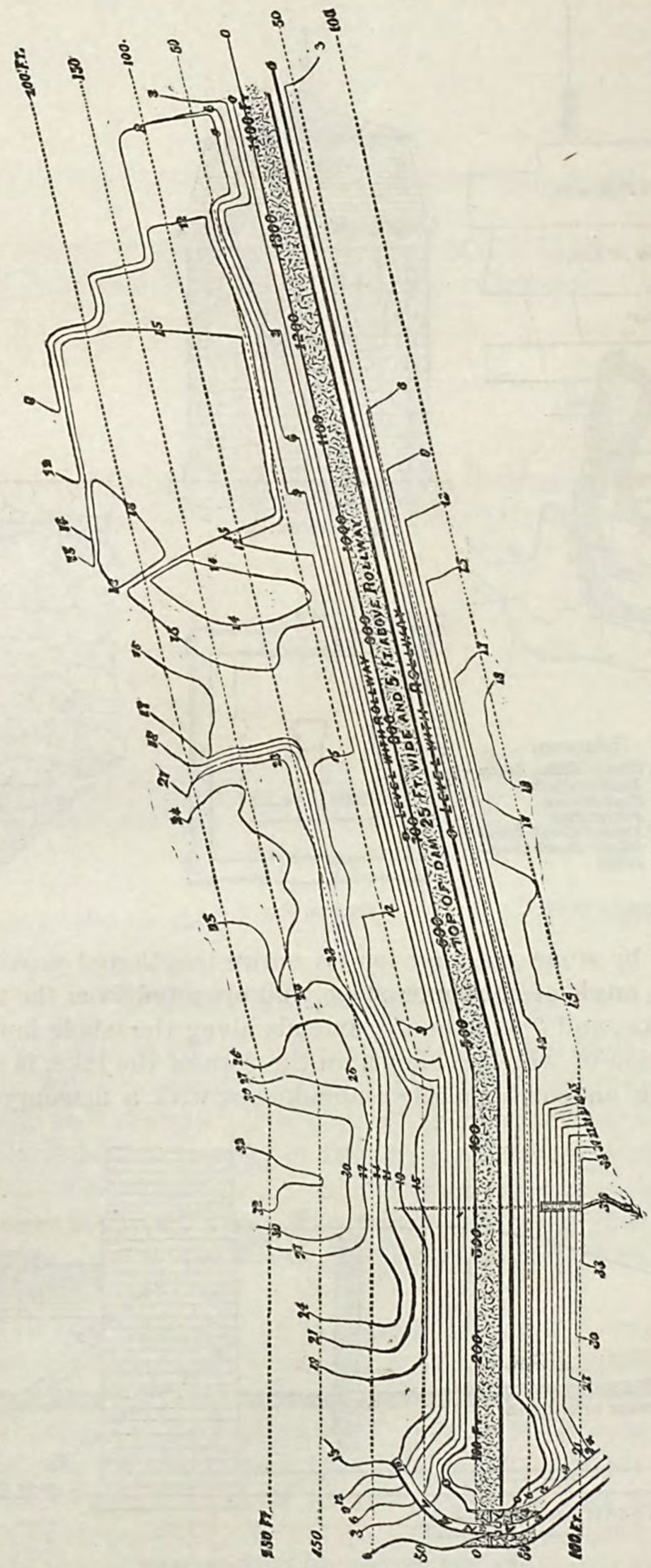


SECTION THROUGH LUDLOW DAM.

thickness, which rests on a stratum of gravel and hard pan, and 18 inches below the foundations of the remainder of the dam. This wall, of rubble in cement, is built in two vertical courses, separated by a space 6 inches in width filled with concrete, the total height being 21 feet 6 inches, and rising to within 2 feet of the top of the enbankment. The total length of the dam is 496 feet, the priming-wall being of the same height. Width of banks at top 35 feet; inner slope 2 to 1, outer 4 to 1; the former paved with stone as in the other dam. The top is 4 feet above high-water surface. The depth of water in front of this dam averages 14 feet. The cut shows the construction of this

dam. Another cut shows the details of the gate-house, which contains two outlets—one 30 inches in diameter, running nearly through the dam, and one 24-inch supply-main. The former is for use when the consumption shall increase in the future. The whole gate-house measures 18 feet 6 inches by 19 feet 6 inches on the outside, and, as shown in plan, can be divided into three chambers by stop-planks sliding in grooves in the masonry. At present a set of sliding screen is placed in the compartment of the 24-inch main.

One end of this dam is 100 feet and the other 300 feet distant from the so-called filter-dam. This extends across the arm of the lake directly in front of the Ludlow dam, and is a dry rubble wall forming a retaining-wall for



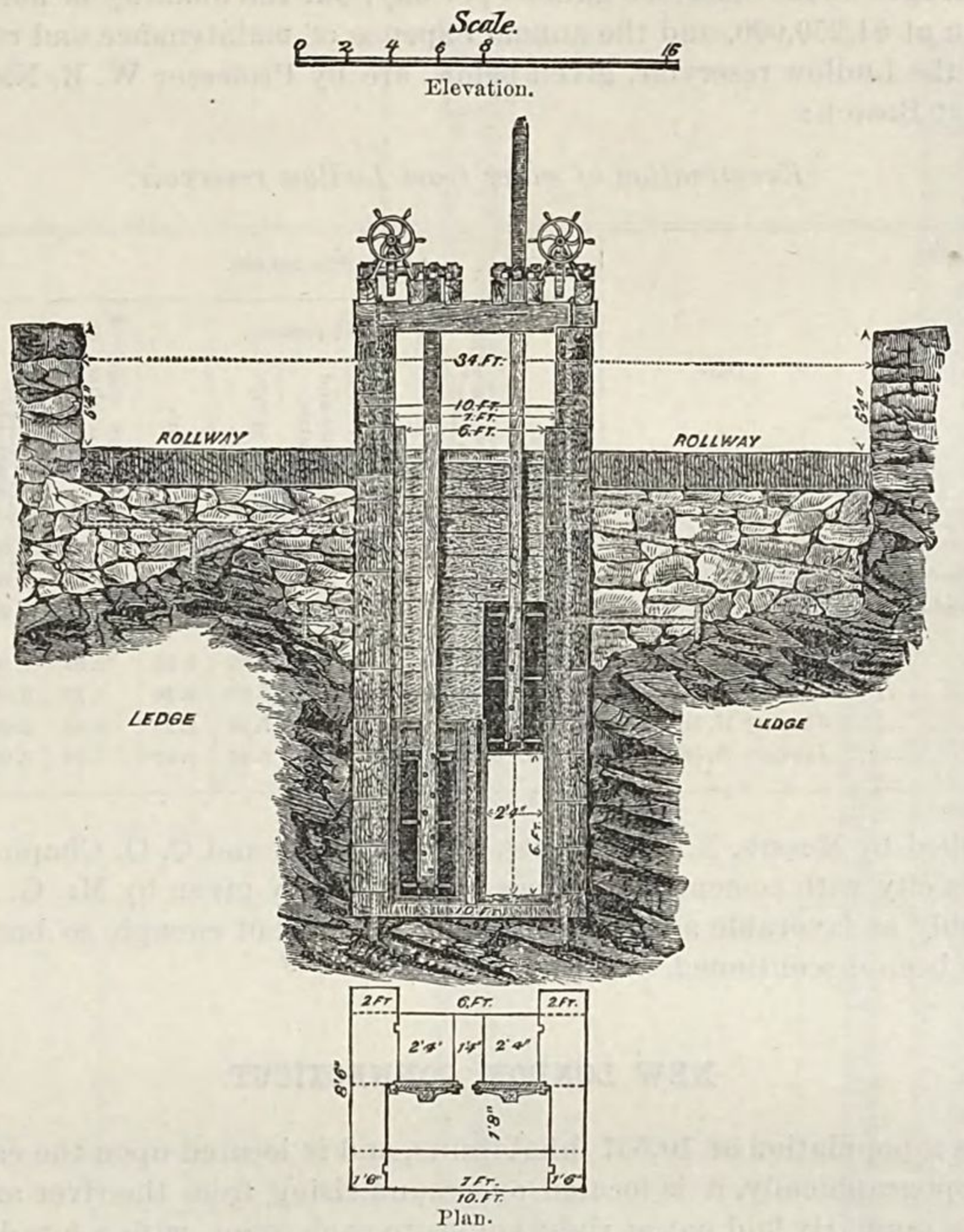
PLAN OF CHERRY VALLEY DAM.

a quantity of sand, and leaving an open space 100 feet long, in which filtering-screens may be placed on frame-work. Over this space a bridge is built. The space between the filter and the Ludlow dam is covered with a layer of clean sand.

From this reservoir 56,410 feet of 24-inch main conveys the water into the city through 3,736 feet of cast iron, 52,506 feet of wrought iron cement-lined, and 168 feet of wrought-iron tube. The cement pipe is coated and bedded in cement. Owing to the defective character of the foundation of the Cherry Valley dam a large amount of

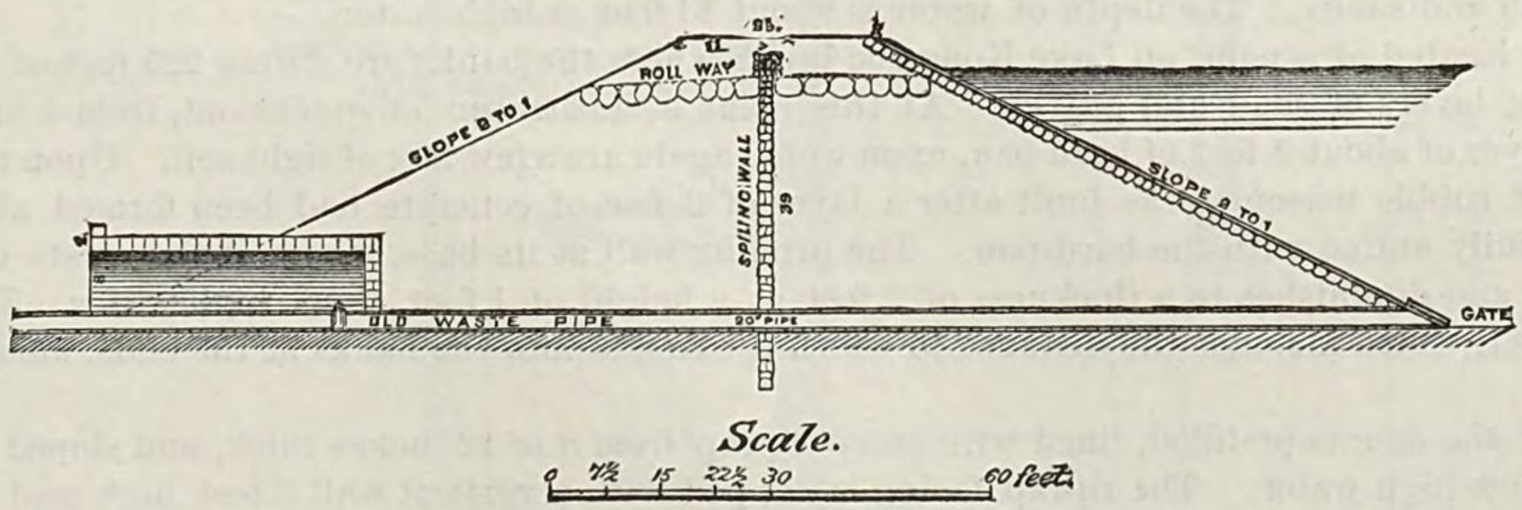
leakage takes place beneath it, and it was found necessary to build a set of waste-gates in the roll-way or waste-weir as a sort of safety-valve. A plan and elevation are annexed. This permits the drawing off of the water very rapidly in case of any impending failure of the dam.

The position of the waste-weir is shown in the plan of the dam. The capacity of discharge of these safety-gates is estimated at 540 cubic feet per second to draw off the first foot of water below the top of the weir.



ROLL-WAY AND WASTE-GATES, CHERRY VALLEY DAM.

The area of the Van Horn reservoir at high-water level is 10 acres, with a capacity of about 100,000,000 gallons. It is irregular in outline, with an earth dam about 1,000 feet long, having a clay-puddle priming-wall 12 feet thick at base and 4 feet at top. The total width of the bank at the top is 15 feet, with slope of 2 to 1, and a total height of 30 feet. The reservoir was built in 1867 by the water company at a cost of $10,000. One 20-inch and



one 12-inch pipe convey the water from the gate-chambers. This was followed by the construction of the smaller Lombard reservoir, which is identical in construction with it, the dam being 250 feet long and 30 feet high, with a capacity of 10,000,000 gallons and an area of 3 acres. There are two effluent pipes, as before. It was finished in 1868 at acost of $2,000. The two dams of the Ludlow reservoir are said to have cost $113,400. The drainage area of the Van Horn and Lombard together has been estimated at about 4,299 acres.

The elevation of the Van Horn reservoir at water-level is 198 feet above city datum, and the depth 30 feet. Of the Lombard the high-water surface is also 198 feet above datum, and depth 22 feet.

The distribution system contains 55 miles of cast-iron and cement-lined wrought-iron pipes, divided about as follows: 1¼-inch, 211.0; 2-inch, 8,782.0; 3-inch, 58,564.0; 4-inch, 41,926.0; 6-inch, 63,372.5; 8-inch, 54,726.0; 10-inch, 8,905.0; 12-inch, 20,283.0; 16-inch, 22,180.1; 20-inch, 4,364.5; 24-inch, 56,524.5; total, 339,838.6 linear feet.

The sizes in use may be seen from the table. There are 378 Matthews' patent fire-hydrants in use. This system supplies about 3,500 water-takers, representing about that number of service-pipes.

The consumption averages about 3,000,000 gallons per day, but the quantity is not exactly known. The first cost of the works is given at $1,250,000, and the annual expense of maintenance and repairs for 1879 was $10,369. The analyses of water in the Ludlow reservoir, given below, are by Professor W. R. Nichols, of the Massachusetts Institute of Technology, at Boston:

Examination of water from Ludlow reservoir.

Locality.	Date.	Parts per 100,000.							Grains per United States gallon.					
		Ammonia.	"Albuminoid ammonia."	Solid residue.			Chlorine.	Oxygen required to oxidize organic matter.	Ammonia.	"Albuminoid ammonia."	Solid residue.			Chlorine.
				Inorganic.	Organic and volatile.	Total at 212° F.					Inorganic.	Organic and volatile.	Total at 212° F.	
Reservoir near entrance of Broad brook	December 25, 1875	0.0084	0.0172	3.60	2.16	5.76	0.20	0.82	0.0049	0.0100	2.10	1.26	3.36	0.12
Center of reservoir 6 feet below surface	December 25, 1875	0.0162	0.0314	3.52	2.88	6.40	0.21	1.31	0.0094	0.0183	2.05	1.68	3.73	0.12
Between gate-house and filter 6 feet below surface.	December 25, 1875	0.0164	0.0320	3.36	2.92	6.28	0.22	1.45	0.0094	0.0187	1.96	1.70	3.66	0.13
Broad brook near reservoir	January 17, 1876	0.0066	0.0128	3.14	1.88	5.02	0.20	0.89	0.0038	0.0075	1.83	1.10	2.93	0.12
Reservoir	January 17, 1876	0.0126	0.0316	2.64	2.44	5.08	0.20	1.33	0.0073	0.0184	1.54	1.42	2.96	0.12
Reservoir, second sample	January 17, 1876	0.0152	0.0318	2.40	2.64	5.04	0.20	1.49	0.0089	0.0185	1.40	1.54	2.94	0.12
Between filter and gate-house	January 17, 1876	0.0120	0.0340	2.46	2.98	5.44	0.20	1.29	0.0070	0.0198	1.43	1.74	3.17	0.12

The works are controlled by Messrs. N. W. Talcott, S. W. Porter, and C. O. Chapin, water commissioners.

The experience of this city with cement-lined pipes is thus tersely given by Mr. G. A. Ellis, the city engineer: "Our experience is probably as favorable as any in the country, but not enough so but that its use for new work for the last five years has been discontinued."

NEW LONDON, CONNECTICUT.

New London contains a population of 10,537 inhabitants, and is located upon the eastern bank of the Thames river near its mouth. Topographically, it is located on ground rising from the river and more or less hilly. The principal streets are pretty regularly laid out at right angles to each other, with a few diagonal or irregular streets intersecting.

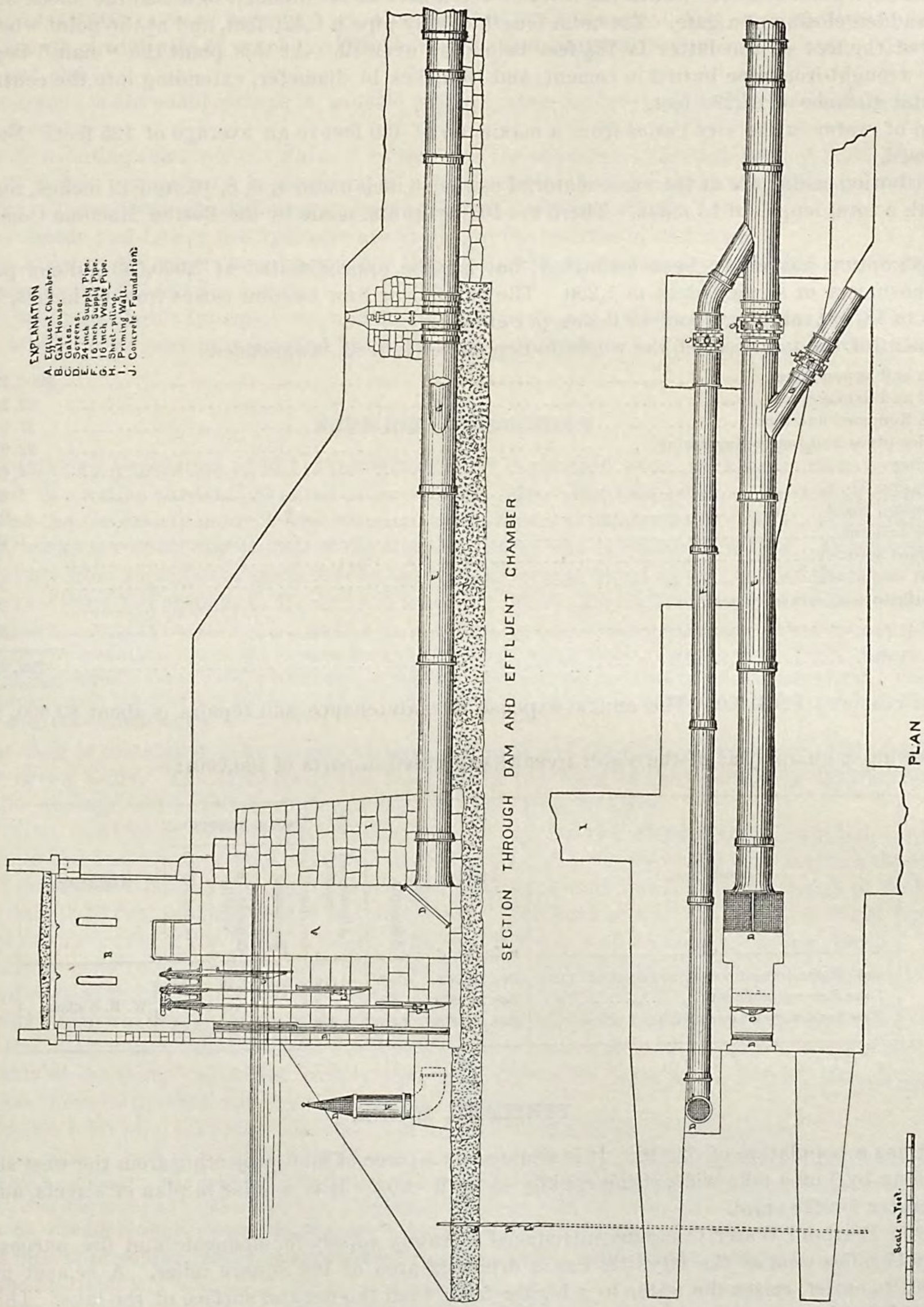
Water was first introduced into the city in 1872 by the city authorities, and is derived by gravity from an artificial reservoir known as lake Konomoc, situated about 6 miles out of the city. The water-shed of the lake is calculated at about 1,296 acres, while the area of the water-surface in the lake is 225 acres. The storage capacity is estimated at 600,000,000 gallons. The bottom was cleared of muck, stumps, etc., and the soil remaining was principally clean and sandy. The depth of water is about 13 feet at high water.

The dam is located at a point on Lake Konomoc brook where the banks are within 225 feet of each other, and are composed of layers of sand and gravel. At this point a substratum of quicksand, from 4 to 6 feet thick, is overlaid by a layer of about 2 feet of hard pan, upon which again are a few feet of light soil. Upon the hard pan the priming-wall of rubble masonry was built after a layer of 2 feet of concrete had been formed about 10½ feet in width and carefully united with the hard pan. The priming-wall at its base, where it thus rests on the concrete, is 4½ feet thick, and diminishes to a thickness of 2 feet at a height of 1 foot above high water. The total length is about 275 feet, which includes the distance to which it extends into the banks at the ends, amounting to about 50 feet.

The face of the dam is puddled, lined with stone riprap from 8 to 12 inches thick, and sloped 1½ to 1 up to a point 1 foot below high water. The riprap facing is capped with a vertical wall 5 feet high and from 2 to 4 feet thick. The back of the dam is gravel-banked to a slope of 1½ to 1, and giving the total width at the top of 25 feet, the priming-wall being in the center. The overfall, as detailed by Mr. W. H. Richards in his report of 1873, is situated in the center of the dam, is 9 feet thick at the bottom and 4 feet at the top, surmounted by caps of dressed masonry 2 and 2½ feet wide, respectively. The 2-foot caps are 6 inches above the edge of the overfall, and at this point the latter is 15 feet wide; above the 2-foot caps the width of the overfall between the wing-walls is 25 feet. The wing-walls flank the overfall, and are 7 feet 6 inches wide at base, terminating 3 feet wide at the level of the top of the dam.

A chestnut apron laid in concrete and extending 12 feet in front of it, together with a 2-inch sheet-piling, protects the dam from being washed away in front of the overfall. A paving of the space between the wing-walls extends also 45 feet from the apron.

The effluent chamber east of the overfall is 4 feet by 4 feet 6 inches inside, with a screen opening 30 inches wide, having three cast-iron gates at different depths, each 24 by 30 inches. The screens are copper wire with $\frac{1}{8}$-inch



NEW LONDON WATER WORKS.

mesh. The gate-house above the effluent chamber is of masonry, and 8 by 10 feet by 9 feet high, containing the hoisting machinery. From the effluent chamber a 24-inch cast-iron pipe runs through the dam and connects with the main conduit.

On account of the substratum of quicksand, it was deemed advisable to drive a row of sheet-piles 8 or 10 feet into the quicksand 20 feet in front of the priming-wall and through the hard pan. The piles were tongued and grooved and 2 inches thick, and fastened together by bands of 6-inch pine timber.

About 1 mile above the dam a filter dam 20 feet wide by 12 feet high, of loose gravel, is built and used as a driveway.

The main conduit is of Scotch-clay pipe, such as is employed in sewer construction, and 24 inches in diameter, laid in 3-foot lengths with cement joints.

A stand-pipe situated 6,826 feet from the dam consists of a 20-foot vertical wrought-iron pipe 20 inches in diameter, with its top about 2 feet above the level of the lake. It is intended to lessen the shock on the conduit caused by a sudden closing of a gate. The total length of clay pipe is 6,826 feet, and at the point where the stand-pipe is located the foot of the latter is 18½ feet below the overfall. At this point the "main" begins. It is a cement-lined wrought-iron pipe buried in cement, and 16 inches in diameter, extending into the central portion of the city, a total distance of 27,290 feet.

The head of water in the city varies from a maximum of 180 feet to an average of 125 feet. No distributing reservoir is used.

The distribution mains are of the same material as the 16-inch main, 4, 6, 8, 10, and 12 inches, respectively, in diameter, with a total length of 15 miles. There are 109 hydrants, made by the Boston Machine Company, and 89 gates.

The consumption has never been estimated, but may be approximated at 2,000,000 gallons per day. The number of consumers or service-pipes is 1,250. The rainfall in New London varies from 60 inches, as in 1874, to 40 inches, as in 1878, averaging about 48 inches per annum.

A statement of the total cost of the works to September 1, 1880, is appended:

Pipes and appendages	$200,794 30
Land and damages	22,365 89
Lake Konomoc and dam	37,974 45
Service-pipes and temporary mains	22,091 70
Fencing	4,850 72
Extension No. 3	467 06
Extension No. 4	918 30
Meter account	1,196 18
Hydrant account	54 77
Street commissioners	326 70
Manufacture of service-pipes	800 00
Cash	366 37
Total	292,206 44

The first cost was $264,000. The annual expense of maintenance and repairs is about $3,000, not including interest.

The following is an analysis of the water (results expressed in parts in 100,000):

Locality.	Date.	Ammonia.	"Albuminoid ammonia."	Solid residuum. Inorganic.	Solid residuum. Organic and volatile.	Solid residuum. Total at 212°F.	Authority.
Lake Konomoc near bottom, at a depth of 25 feet	Dec. 23, 1879	0.005	0.016	1.60	1.20	2.80	W. R. Nichols.
Lake Konomoc at outlet	Dec. 23, 1879	.....	.....	.....	.....	3.00	W. R. Nichols.
New London, water commissioner's office	Dec. 11, 1879	0.006	0.008	.....	.....	3.88	W. R. Nichols.

PORTLAND, MAINE.

Portland has a population of 33,810. It is situated on a piece of land projecting from the west shore of Casco bay, 3 miles long by ¾ of a mile wide, rising rapidly at both ends. It is regular in plan of streets, and is chiefly a commercial center for the state.

In 1869 the Portland Water Company introduced a gravity supply for domestic and fire purposes from lake Sebago, lying 17 miles west of the city. It has a drainage area of 100 square miles. A cement masonry dam, constructed at its outlet, raises the water to a higher level than the natural surface of the lake. This dam is 148 feet long and 15 feet high, with a thickness of 13½ feet at bottom and 6½ feet at top, a perpendicular back and a sloping face of 7 horizontal to 15 vertical. Its cost is approximated at $40,000. There is no gate-house connected in the dam with the main conduit, but the latter comes from a different part of the lake by a conduit of wood 4 feet square, extending 80 feet out into the lake. At a brick gate-house, 27 by 33 feet, on the bank, this wooden conduit enters a brick conduit 2½ by 3½ feet and 2,000 feet long, when it enters a tunnel 3½ feet high, 6 feet wide, and 1,360 feet long, with a fall of 1.775 feet. Another length of 2,080 feet brick conduit with semicircular crown and curved

invert connects at another gate-house, 15 feet square, with two cement-lined wrought-iron pipes, one 20 inches in diameter and 83,119 feet long, the other 26 inches in diameter and 18,500 feet long, whence it is diminished to 24 inches in diameter and extends to the city side by side with the 20-inch pipe, a distance of 63,669 feet, making two main conduits entering the distributing reservoir. The high-water surface in the lake is 267 feet above mean tide in the bay.

The distributing reservoir is nearly square in plan, with earth embankments, puddle-faced to a depth of 18 inches, and is protected by a stone riprap 8 inches thick. Thickness at top of banks, 20 feet; depth when full, 28 feet; capacity, 12,000,000 gallons; area of high-water surface, 62,463 square feet; area of bottom, 32,100 square feet; average length of each side at water-line, 250 feet. The surface is 160 feet above tide-water. The banks slope 1½ to 1 inside and out.

The water-supply is abundant, except in unusual seasons when the level of the lake has been seriously lowered by prolonged drought.

From the distributing reservoir the water is supplied to the consumers through cement-lined pipes 16, 12, 10, 8, 6, 4, 3, and 2 inches, respectively, in diameter, of a total length of 65 miles, at the estimated rate of 4,500,000 gallons per day. The number of consumers or water-takers in 1880 was 4,414.

Both the Johnson and Lowry fire-hydrants are in use, to the number of 202 in all.

The original cost of the works is unknown, but they have cost, up to January, 1880, the sum of $2,251,000, the running expenses being $10,000 per annum.

The water is of remarkable transparency, and contains 6.8 parts per 100,000, or 1.5 grains per gallon of inorganic matter. The works are at present controlled by D. W. Clarke, president, and George P. Westcott, superintendent and secretary.

NORWICH, CONNECTICUT.

Norwich contains a population of 15,112 inhabitants. It is situated upon the Thames river near the mouth of the Yantic, and in a valley surrounded on all sides by high hills. Portions of the town are much more elevated than others, and the streets are more or less irregular. The business interests are chiefly manufacturing.

The water-works are under the control of the city, and water was introduced in 1869. It is a gravity system, deriving its supply from a number of small brooks and springs located about 2½ miles out of the city. The engineer of the work was James T. Fanning, C. E., and the following details are obtained from his "Memoranda":

> The water-shed lies along the summit of a section of the range of high land between Scotland road and Canterbury turnpike, and the site of the reservoir is in the valley on the western slope of this range, which leads its waters to the Yantic river. On the western slope of this range, and opposite the site of the reservoir, lies another valley running eastward to the Shetucket river. These two streams at one point approach each other within 500 feet. About 1 mile below this the dam is located. A dam 30 feet high gives an overflow into the eastern from the western valley.

The water-shed is calculated to be about 483 acres, according to the surveys, with a rainfall of 55.89 inches as an average of seven years. The capacity of the reservoir to the level of the overflow is 350,000,000 gallons; its length, 1⅛ mile; average width, 480 feet; depth, 16½ feet; and area, 66 acres.

The dam is an earthwork embankment 25 feet wide on top, interior slope about 2 to 1, but convex near the base, as shown in the accompanying cut; exterior slope, 1½ to 1. A priming-wall is built through the center of this, 5 feet thick at base and 2 feet at the top, of stone laid in cement, and founded upon a ledge of rock. The total height of the dam is 35 feet, and length 468 feet on the top. The head of water in the town varies from 135 to 250 feet, the latter at tide-water in the Thames river. The dam is faced with 18 inches of stone riprap.

The well-house construction may be seen from the drawing, and consists of a "circular masonry tower built up through the interior of the slope to above the water-line". Diameter on inside, 8 feet.

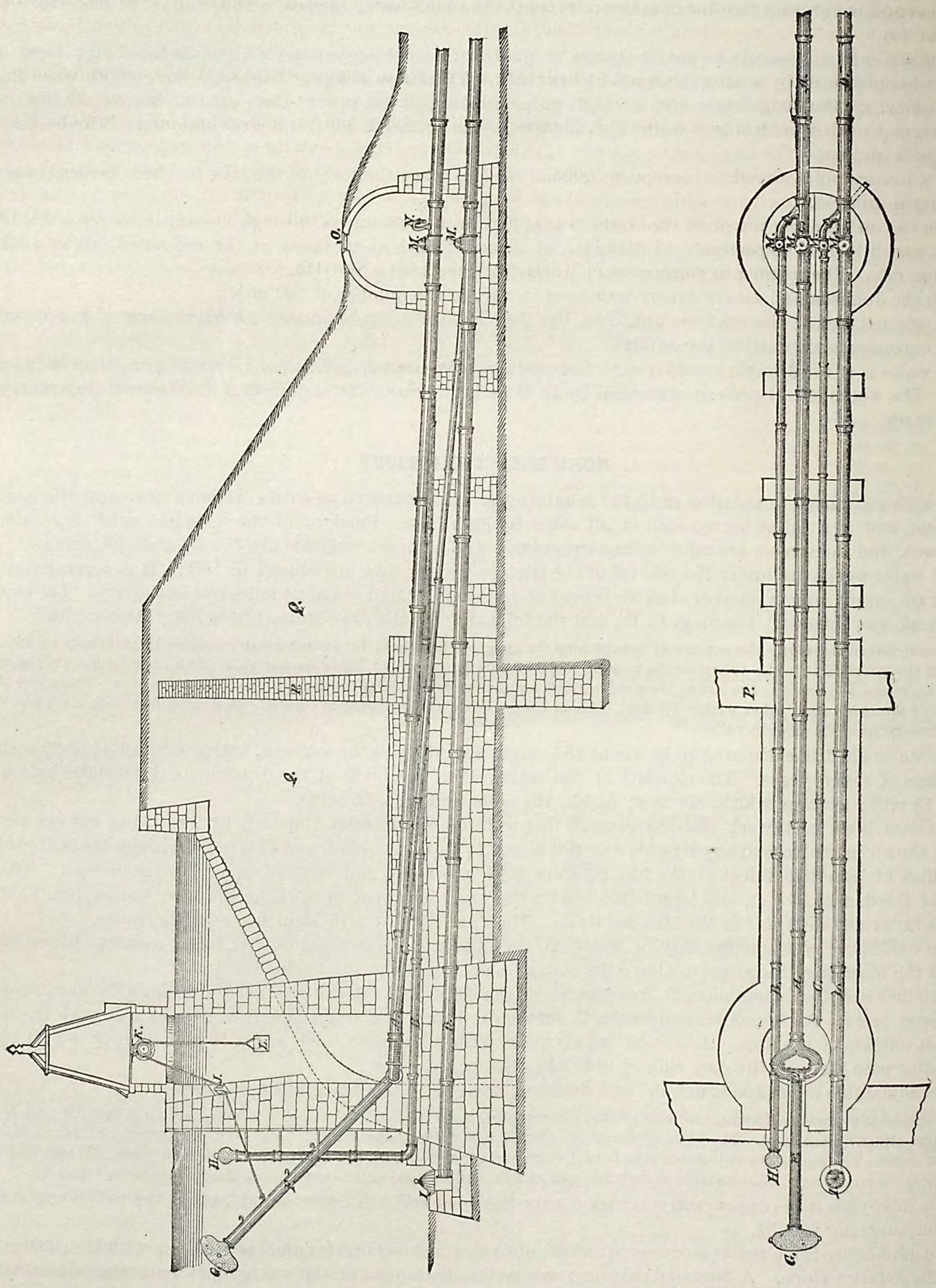
A 16-inch cast-iron waste-pipe, D, from the toe of the slope at the well-house passes through the dam, supported on masonry piers. An 8-inch branch-waste, C, serving to empty the well-house, runs side by side with the former, joining it outside of the dam. A 16-inch supply-pipe, with adjustable inlet, and a 10-inch branch supply-pipe, A and B, also pass through the dam side by side like the wastes.

The adjustable inlet pipe is unique, and deserves mention in the words of its engineer:

> A Y-shaped pipe-casting, forming the base of the effluent pipe, rests on the floor of the well-house, and is connected with the main supply-pipe already mentioned. The arms of the Y are curved into heart-shape toward each other, are flanged at their ends, and 14 inches diameter. The foot of the adjustable pipe is in ⊥-form and connected with the heart-arms by flexible joints allowing free motion in a vertical plane. Length of adjustable or movable arm 27 feet, and its end can be raised above the surface of the water.

This inlet-pipe is of copper, and a screen covers the open end. A block and tackle in the well-house supports a counterbalancing weight.

The gate-house is a circular stone construction of 11 feet inside diameter and the top even with the surface at the toe of the exterior slope. A masonry culvert receives the discharges of the waste-pipes heretofore described, and empties into the brook below the dam. A rubble-masonry wall is built 3 feet high entirely around the basin, with appropriate passage-way and surface-wash culverts. About 20,000 stumps were cleared from the bed of the reservoir during the construction. The level at high water in the reservoir is 4 feet below the top of the dam. The reservoir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has been stocked with fish, and serves both as impounding storage and for distributing. The water is brought from the reservoir to the city through a cement-lined wrought-iron pipe buried in cement and 14 inches in diameter, of 9,000 feet length, and one 16-inch cast-iron main 9,000 feet long. The distribution is accomplished by about 31 miles of cement-lined pipes with some considerable lengths of cast iron. The sizes used are 10-, 8-, 6-, 5-, and 4-inch.

The number of water-takers averages about 3,000, and the consumption is estimated at from 750,000 to 1,000,000 gallons per day.

Two hundred and forty-seven gates and 254 hydrants are in use at the present time, the latter being made by the Boston Machine Company.

The original cost of the works was about $272,000, including about 9 miles of distribution mains, one 14-inch main, and 68 hydrants. The total cost to January 1, 1880, is about $411,879, and the annual expense of maintenance and repairs, not including interest, is about $4,000.

The city is about to construct additional works to supplement the present insufficient supply.

The quality of the water may be seen from the appended analysis by Professor Silliman, made in 1873, to be of exceptional purity and softness.

The present engineer and superintendent is Mr. H. B. Winship, of Norwich, Connecticut.

Analysis of the water.

[Results expressed in grains per gallon.]

Sample No.	Source.	Mineral matter.	Organic and volatile.	Total solid.	Degrees of hardness.
1	22 feet below lake surface	1.166	0.70	1.860	0.560
2	12 feet below lake surface	1.149	0.60	1.749	0.540
3	Surface of lake	1.050	0.58	1.630	0.510
4	Waste-pipe of lake	1.399	0.70	2.099	0.560
5	House faucet	1.071	0.79	1.866	0.560
	Average	1.167	0.67 9/10	1.844	0.546

CONCORD, NEW HAMPSHIRE.

Concord, with a population of 13,843 inhabitants, is located on the right bank of the Merrimack river. It stands on level ground, gradually rising from the river-bank upon a granite formation. Its industries are manufacturing, the products being agricultural implements, belting, wagons, and cotton and woolen goods.

In 1873 the municipal authorities introduced water into the city from Pennacook lake, formerly known as Long pond, 300 acres in extent, and situated about 2.84 miles in a northwesterly direction from the center of the city. The drainage area of this pond is 3 square miles, and the elevation of high-water surface is 122 feet above Main street opposite the state-house. A dam has been built across the outlet of the lake, about 2,000 feet below an old dam, adding 200 acres of water-shed. The soil is sandy and is underlaid by granite.

The dam is an earth embankment, 110 feet long at bottom by 280 feet at top, 100 feet wide at bottom and 20 feet at top. Total height 20 feet, with a slope of 2 to 1 outside and in. Through the center of this dam, extending the whole length, is a masonry priming-wall of granite in cement, 3½ feet thick at base and 2 feet thick at top. The face of the dam is protected by a riprap wall of quarried granite in cement.

The top is used as a driveway, connecting the opposite sides of the creek. A masonry gate-house rises through the upstream side of the dam, 13 feet square at the base, tapering to 10 feet square at the top, a height of 23.5 feet of masonry, and connects by a bridge with the top of the dam. From this three cast-iron pipes, two of which are 18 inches and one 24 inches in diameter, extend through the dam. One of the former connects with the main to the city for the present supply, and the other is for use at a future period, when an additional line of conduit shall connect with the city. The 24-inch pipe supplies the power to mills located below the dam, and the flow through it is regulated by a gate operated within a small gate-house 8 feet square, of brick, on the lower side of the dam. About 300 feet north of the main dam an overflow 40 feet wide has been built, the top being 4 feet below the crest of the dam, the elevation of which is 185 feet above low-water mark on the Merrimack.

A brick conduit has been built, connecting the outlet below the lower dam with the water of the upper pond. This conduit is 2,000 feet long and 26 by 30 inches in diameter. Both ends are closed by gates.

As the water has to be measured, three Gem meters are placed in the iron supply-mains 200 feet below the dam. This is the only instance in the country where the whole supply is measured, and is due to the limited amount allowed by the mill-owners using the power of the stream and originally owning the rights. These meters are inclosed in a stone chamber 10 by 16 by 8 feet, and covered with earth. They are fitted into the two 16-inch iron mains from the reservoir, which combine on leaving the meters into one 14-inch main of cement-lined wrought iron, 3½ miles in length to the city. The distribution mains are 4, 6, 8, 10, and 12 inches, respectively, in diameter, all of cement-lined wrought iron, with a total length of 23 miles. Ninety-six Matthews patent fire-hydrants are in use. The daily consumption averages 575,000 gallons to 2,000 water-takers.

The cost of the dam was $19,523, and the appended list of items will show the total cost up to April, 1875, the date of the completion of the works:

Summary of all expenditures to December 31, 1873.

Conduit and works at Long pond	$20,360 53	Engineering and superintendence	$6,955 87
Main pipe	44,411 15	Incidentals	2,396 37
Distribution pipe	99,471 59	General construction	895 26
Gates and hydrants	18,106 18	Damages	61,687 60
Service-pipe	11,401 24		
Dam, gate-house, and appendages	19,523 99	Total	285,777 70
Shop and tools	567 92		

Disbursements, January, 1874, *to April,* 1875.

Maintenance and care of works	$1,808 52	Interest on the same	$1,457 80
Extensions of distributing pipes, 6-inch and 4-inch	2,554 60	Buildings and water-privilege of Farnum & Humphrey	5,000 00
Extensions of distributing pipes, 1-inch and ¾-inch	2,900 60	Cooledge land and water rights	5,500 00
Service-pipes	4,839 18	Meters	283 30
Long Pond works	2,292 58	General construction	1,249 27
Flowage on the shores of Long pond	900 00	Pipe purchased and on hand	324 60
Amount paid Torrent Aqueduct Company and Nathaniel White	20,000 00	Total	49,110 45

The pipe of the whole system is distributed as in the appended table:

	Feet.		Feet.
30-inch main	1,950	6-inch distribution	37,911
16-inch main	151	4-inch distribution	45,240
14-inch main	13,556	1-inch distribution	11,747
14-inch distribution	3,704	¾-inch distribution	9,830
12-inch distribution	1,622		
10-inch distribution	3,034	Total	137,412
8-inch distribution	8,667		

The total cost of the works to date has been somewhat over $350,000, with an annual cost for the year 1879 of $2,468. The water, coming largely from a granitic region, compares favorably with that in other cities in purity. The analysis of the water from Long pond, made by S. Dana Hayes, state assayer of Massachusetts, in 1872, shows the following results:

	Grs. per gal.
Inorganic matter	0.32
Organic matter	1.48
Total impurities	1.80

RUTLAND, VERMONT.

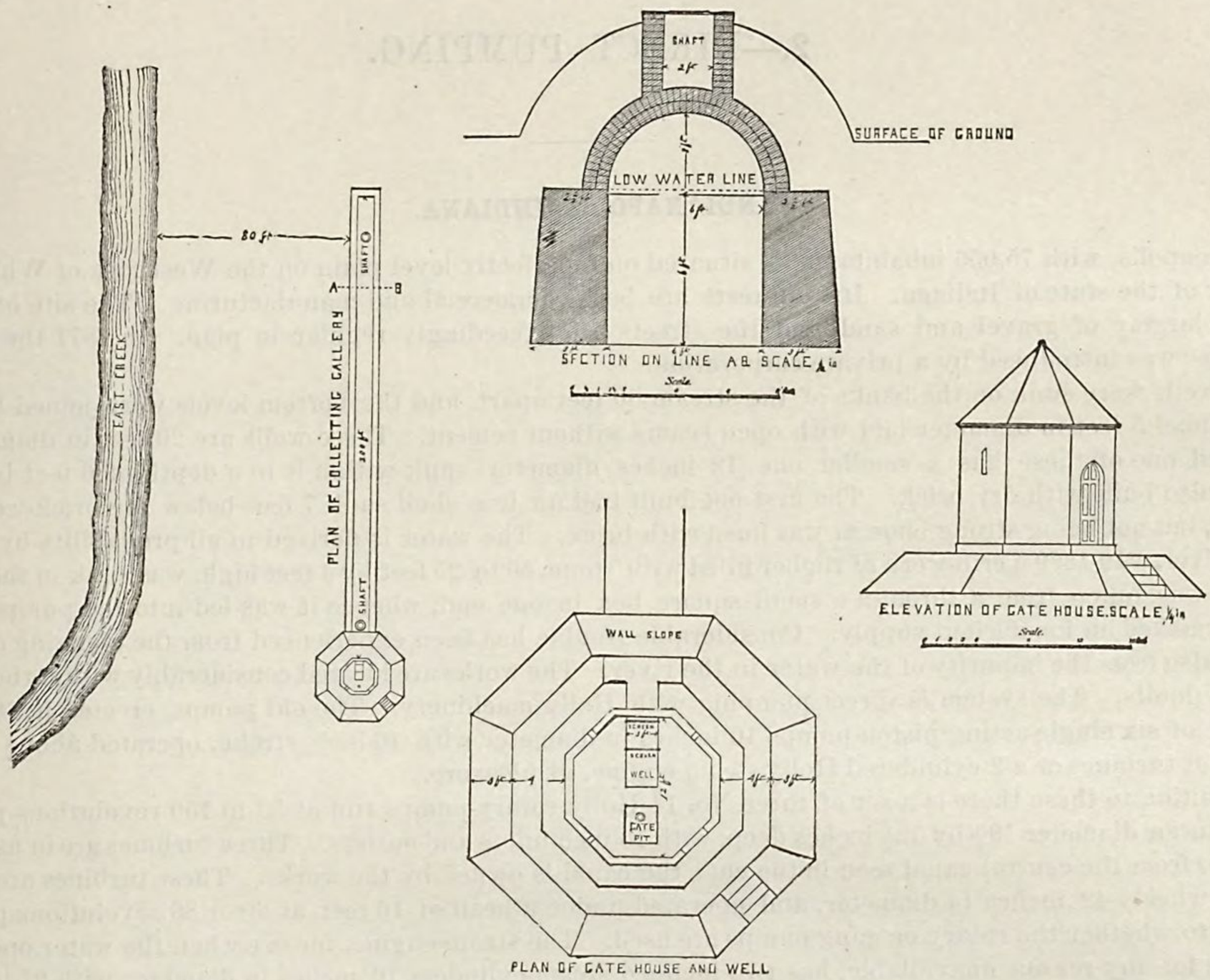
This city, situated near the center of the state, contains a population of 7,502 inhabitants. The city is situated in a narrow basin surrounded by considerable hills, and its streets are of steep grade in very many cases, with but little regularity in plan. The strata underlying the city proper are generally Æolian limestone of considerable thickness, with substrata of quartz-rock. A narrow outcrop of Pliocene (Tertiary) makes its appearance a short distance to the east, separating the limestone from the quartz, but does probably not extend beneath the city.

Water for domestic purposes was first introduced into the city in 1853 by the city authorities. It is supplied by two small streams, known as East creek and Tanyard brook, rising in a spur of the Green mountains, about 3 miles east of the city. The North brook falls rapidly in its course, in some cases as much as from 10 to 40 feet in short distances, making the formation of any considerable sheet of water by damming an impossibility. A reservoir, however, has been built in the bed of the stream, and a main carries the water to the distributing reservoir in town, about 1 mile from its center. This piping consists of 350 feet of 6-inch cast-iron pipe, followed by a length of 350 feet of 5-inch pipe, and the remaining distance, equal to 10,025 feet, is 6-inch cast iron, a total of 2.03 miles. From a similar construction on East creek a length of 3⅛ miles of 12-inch iron pipe brings the water to the reservoir in town as before. The connection with the reservoir is so arranged that the water can be sent to the town through the reservoir or around it, or from both reservoir and conduit. The drainage area of these streams has never been accurately ascertained by survey. The annual rainfall upon their water-sheds has been averaged from observations of ten years' duration at 36½ inches, of which perhaps 65 per cent. is collected in the drainage-basins, owing to the abruptness of their slopes.

The dam on Tanyard brook is constructed of cement masonry, and is but 15 feet long by 8 feet thick at base and 4 feet at top. It contains no gate-house, the outlet-pipe having a plug fitted into it on the upstream side of the dam. The supply from East creek was introduced in 1876, and the collecting gallery built as shown. The

North Brook water-shed has been estimated at 900 acres, yielding an average daily supply of 1,400,000 gallons. The actual comsumption, as estimated, is 1,250,000 gallons per day, supplied to about 900 takers.

The distributing reservoir is an earthwork trapezoidal in plan, 65 by 67½ by 35 by 58 feet, and 15 feet deep. A central puddle-wall, running through the embankments, is 4 feet thick. The slope of the faces inside and out is 1½ to 1, the former being faced with riprap 6 inches thick. The capacity is calculated at 1,250,000 gallons. The maximum head from this to the lowest part of the city is 156 feet. The distribution is carried out through cast-iron pipes, 3, 4, 5, 6, 8, and 12 inches in diameter, with a few as small as 2 inches in diameter. Total length, $2\frac{3328}{5280}$ miles.



RUTLAND WATER-WORKS.

The records of the cost having been burned in a recent fire, it is only approximated at $28,500, with an annual expense for maintenance and repairs of $2,000 (in 1879). Fifty Matthews' patent fire-hydrants are used.

Rutland presents one of the most economical systems in the country for a city of its size, so far as the original cost is considered. The water, which is roiled during freshets, is of good quality at other seasons, as the following analysis by Professor Nichols will show. The sample was taken from an ordinary tap on the service-mains in town. Results are expressed in grains to a United States gallon:

Ammonia	0.0026
"Albuminoid ammonia"	0.0048
Inorganic matter	2.0
Solid residue—organic and volatile	0.3
Total at 212° Fahrenheit	2.3
Chlorine	0.06
Hardness	1.2°

The works are at present under the superintendence of Mr. J. M. Davis.

The accompanying cut shows the construction of a gallery built about 80 feet distant from the banks of East creek, and collecting the water thence by infiltration through the sandy and gravelly soil intervening.

2.—DIRECT PUMPING.

INDIANAPOLIS, INDIANA.

Indianapolis, with 75,056 inhabitants, is situated on a perfectly level plain on the West fork of White river, in the center of the state of Indiana. Its interests are both commercial and manufacturing. The site of the city is composed largely of gravel and sand, and the streets are exceedingly regular in plan. In 1871 the water from White river was introduced by a private corporation.

Two wells were sunk on the banks of the stream 80 feet apart, and the bottom levels were joined together by a brick tunnel 5 feet in diameter laid with open seams without cement. These wells are 20 feet in diameter at the mouth, and one of these has a smaller one (12 inches diameter) sunk within it to a depth of 6 feet below. The wells are also built with dry brick. The first one built had an iron shell sunk 7 feet below the brick-work and on the inside, but not being strong enough was lined with brick. The water is derived in all probability by infiltration from the river. In 1879 a crib-work of timber filled with stone, 50 by 25 feet by 4 feet high, was sunk in the river, and the water was taken from it through a small square box in one end, whence it was led into the pumps, the wells having furnished an insufficient supply. Considerable trouble has been experienced from the clogging of the inlet-pipe, and also from the impurity of the water in the river. The works are located considerably within the upper line of the city limits. The system is direct pumping with Holly machinery. The old pumps, erected in 1871, consist of a gang of six single-acting piston-pumps 16 inches in diameter with 16-inch stroke, operated above by gearing from a set of turbines or a 2-cylindered Holly steam-engine, at pleasure.

In addition to these there is a set of three No. 14 Holly rotary-pumps run at 50 to 150 revolutions per minute, with an interior diameter $19\frac{3}{4}$ by $12\frac{1}{2}$ inches deep, with 10-inch inlets and outlets. Three turbines are in use, deriving their power from the central canal seen in the cut; the canal is owned by the works. These turbines are Dayton or American wheels 42 inches in diameter, and operated under a head of 16 feet at 60 or 80 revolutions per minute, according to whether the rotary or gang pumps are used. The steam-engine, for use when the water operating the turbines is for any reason unavailable, has two inclined steam-cylinders 16 inches in diameter with 27-inch stroke, operating a fly-wheel supported above them. It is run when in use at a speed of from 75 to 150 revolutions per minute.

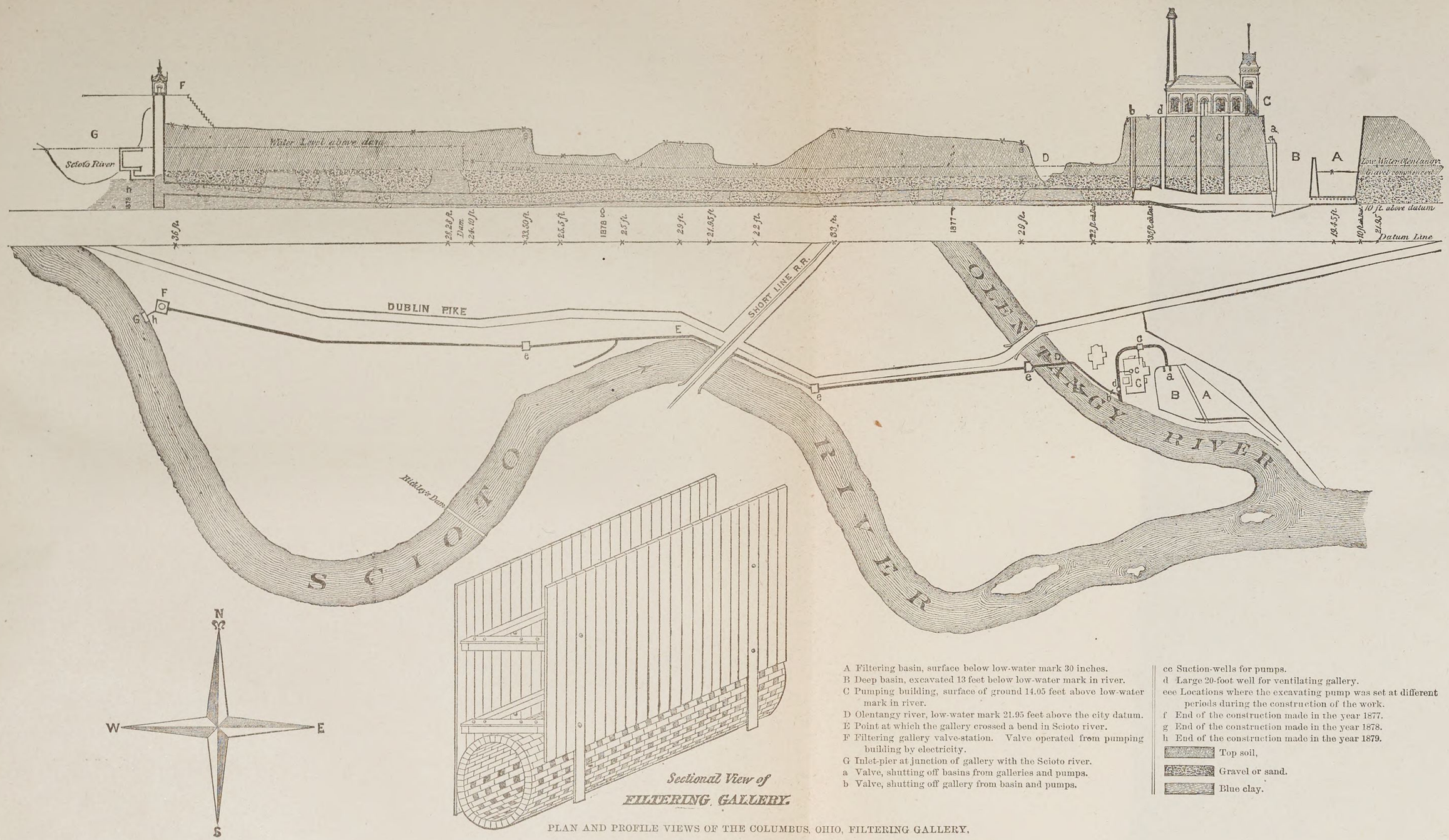
The gang and rotary pumps are soon to be discarded as nearly worn out. In the former there is a single discharge-pipe to each pump, which contains two hinge-valves $3\frac{3}{8}$ by $11\frac{1}{2}$ inches.

The large Holly pumping-engine, built in 1875, is of the inventor's latest pattern. There are four inclined pumps, the rods of which are connected with the piston-rods of the steam-cylinders above them by a key readily detachable. The pumps are 15 inches in diameter with 33-inch stroke; four steam-cylinders 25 inches in diameter, with 33-inch stroke, operated non-condensing or compound condensing. The engine is operated for about one-third of the year. There are twelve suction and twelve discharge valves in each pump-cylinder, 6 inches in diameter by $\frac{3}{16}$-inch lift. The capacity of the pumping-engine is claimed to be 12,000,000 gallons per day, and a test trial is said to have given with best Pittsburgh coal a duty of 86,500,000 foot-pounds. The capacity of the gang pumps is about 3,000,000 gallons per 24 hours, and of the rotary about 2,000,000. They are usually in operation continuously, while the large Holly engine is idle about two-thirds of the year. The condenser of the latter is of the jet pattern, 4 feet 5 inches in diameter by 29 inches deep, with two air-pumps each 22 inches in diameter with 22-inch stroke.

Steam is supplied to the pumping-engines by three batteries of two boilers each. One battery consists of two Holly upright boilers each 7 feet in diameter by 10 feet high, multitubular, with 2-inch tubes, and an evaporation of $11\frac{1}{2}$ pounds of water per pound of coal from Indiana. The pressure in them averages 60 pounds.

In another battery of two boilers the boilers are horizontal 2-flue, 42 inches in diameter by 24 feet length of shell, the flues being 15 inches in diameter. The other battery contains two five-flue boilers 24 feet long and 60 inches in diameter. One of the flues is 15 inches, two 14 inches, and two 12 inches in diameter. The evaporation is 9.8 pounds of water per pound of coal.

The cost of the gang and rotary pumps, with connecting parts and two upright boilers, was $70,000, while the cost of the new engine without boilers was $45,000.



A Filtering basin, surface below low-water mark 30 inches.
B Deep basin, excavated 13 feet below low-water mark in river.
C Pumping building, surface of ground 14.05 feet above low-water mark in river.
D Olentangy river, low-water mark 21.95 feet above the city datum.
E Point at which the gallery crossed a bend in Scioto river.
F Filtering gallery valve-station. Valve operated from pumping building by electricity.
G Inlet-pier at junction of gallery with the Scioto river.
a Valve, shutting off basins from galleries and pumps.
b Valve, shutting off gallery from basin and pumps.

cc Suction-wells for pumps.
d Large 20-foot well for ventilating gallery.
eee Locations where the excavating pump was set at different periods during the construction of the work.
f End of the construction made in the year 1877.
g End of the construction made in the year 1878.
h End of the construction made in the year 1879.
Top soil,
Gravel or sand.
Blue clay.

PLAN AND PROFILE VIEWS OF THE COLUMBUS, OHIO, FILTERING GALLERY.

The water on leaving the pumps is forced directly into the distributing mains, the 24-inch main from the engine being tapped but a few hundred feet from the engine-house.

The distribution system comprises (1880) about 45 miles of cast-iron mains 24, 20, 18, 16, 12, 10, 8, 6, and 4 inches, respectively, in diameter. The average domestic pressure in them varies from 45 to 50 pounds. In case of fire it can be increased rapidly to about 120 pounds.

The number of water-takers being about 1,400, the consumption averages 4,000,000 gallons per day.

There are 600 Holly hydrants on the distribution system, on which the city has to pay $50 each per year.

Meters have been in use in considerable numbers, but for some reason the character of the water was such as to corrode them very rapidly and soon render them useless. As a consequence most of them were abandoned.

The first cost of the works was about $400,000, which has been increased by extensions, etc., to about $1,000,000. The annual cost of repairs and maintenance has averaged $25,000, but for 1880 is given at $65,000, exclusive of interest. The doubtful quality of water supplied has given rise to much complaint, but no correct analysis seems yet to have been made.

The works have recently changed hands, and a new company has organized, with Sidney M. Dyer as president and superintendent.

COLUMBUS, OHIO.

Columbus contains a population of 51,647 inhabitants, and is situated on the Scioto river 90 miles above its mouth. Its streets are laid out with perfect regularity. The site of the city is exceedingly level, resting on a formation chiefly of sand and gravel underlaid with blue clay. Its industries are manufacturing to a small extent, and commerce in grain, wool, and live stock. It may be called principally a residence city.

The water-supply was introduced in 1871, under municipal auspices, and is derived by pumping from an infiltration gallery on the north bank of the Scioto river, and is transmitted to the city by direct pumping with a set of Holly pumps.

The pumping station is located on the northerly bank of a stream known as the Olentangy river, near its confluence with the Scioto, and about 1½ mile from the city hall. From this point a subterranean gallery extends for 1½ mile due west, crossing under the bed of the Olentangy and terminating, as shown on the map, in an inlet-pier on the Scioto river bank. The total length of the gallery, as shown by the profile, is 5,715 feet. It is constructed of open-laid brick below the springing line of the crown, and of brick laid close in cement above said line.

The interior dimensions are 42 inches high by 34 inches wide, the section being oval. The top is protected by palisading, as shown. The whole gallery was excavated, as it was found impracticable to tunnel. The depth below the surface, the dimensions, etc., as well as the character of the material through which the gallery was driven, are shown in the drawing. During the construction of this gallery two pumps were used to remove the water percolating through the soil into the bottom of the trench, and the last day's pumping showed by gauging nearly 2,000,000 gallons supply. One end of this gallery terminates in the water of the river, and a tower rising above the level is furnished with a gate to admit water from the river if necessary; this gate can be operated by electricity from the pump-house. When the works were originally built, it was designed that the water should be derived from the Olentangy river after filtration through the basin represented at A. This basin contained 8,742 feet of filtering surface. The filtering basin A, built on a higher level than B, has its bottom 30 inches below low-water mark in the river. Seven feet below the surface, and on the side next to the river, the basin has a collecting tunnel 18 by 21 inches, which empties into B; from this 14 small porous pipes, all 4½ feet below the surface, radiate beneath the filtering material. This depth of 4½ feet, constituting the filtering material, consists of stones from 2 to 4 inches in diameter at the bottom, decreasing in size to the top, which is composed of a 7-inch layer of fine sand. This basin A is connected with the river directly by a 12-inch valve. The object was to supply any deficiency. The water from A enters the lower basin, B, which is excavated 13 feet below low-water mark. The sides slope 1 to 1, and have a riprap wall of a perpendicular height of 16 feet, above which they slope at an angle of 33°. Area of bottom, 14,294 square feet. Capacity at low-water level in the river, 1,500,000 gallons. The daily filtering capacity of the basin A is 500,000 gallons. On its failure to supply sufficient water, the filtering gallery already described was extended from the inlet-tower on the Olentangy river, underneath the same, to the opposite bank, whence it has been continued each year until it has reached its present length.

From the pump-well in the engine-house water is pumped into the distributing mains by two new-pattern Holly engines constructed in 1870, which are run alternately. Like others of their class, they are operated either as compound condensing or as high-pressure engines. As a usual thing, one cylinder is run at high pressure and the other three condensing. The cylinders are 21 inches in diameter, with a stroke of 30 inches. Engine No. 2 is geared to run at 3½ times the number of revolutions of the pump, while engine No. 1, just mentioned, has its pump-pistons connected directly with the piston-rod of the steam-cylinder. In both engines there are 4 plungers to each pump. The pumps of one set have 27 inches stroke and are 13½ inches in diameter, and the pumps of the other set have a diameter of 12 inches and a stroke of 30 inches. They average from 12 to 30 revolutions per minute, and one or the

other is run constantly day and night. The geared engine has three valves in the suction- and three in the discharge-pipe, of the flap-valve type, each 3¾ inches by 10 inches, with a lift of ¾ of an inch. The other engine has one valve in the suction- and one in the discharge-pipe, each 20½ inches long by 4 inches in diameter, rising $\frac{9}{16}$ of an inch after the manner of a ball-valve. Steam is furnished by two batteries, one containing a pair of multitubular boilers made by the Holly company. One boiler contains fifty-four and the other fifty-six 3¾-inch tubes; the boilers are 60 inches in diameter by 16 to 18 feet length of shell. The other battery contains four double-flue boilers, each 48 inches in diameter and 26 feet long, two of which have 16-inch and two 18-inch flues, and all the boilers are run at a pressure of 70 pounds. The coal used is an inferior grade of bituminous slack, and the evaporative power obtained from both batteries averages 7 pounds of water per pound of coal.

The engines were guaranteed to pump 5,000,000 gallons per day against 60 pounds of water-pressure, and 4,000,000 against 120 pounds pressure, these being, respectively, the domestic and the fire pressure. Connected with each engine is a jet-condenser 3 feet long by 53 inches in diameter, and two air-pumps 16 inches in diameter and 30 inches stroke. For the condensers, cold water is derived by gravity from the river. The cost of the engines from 1871 to 1876, including repairs, was $46,000. The performance of the two engines for the last nine years is given below:

Consumption of slack coal—ashes and cinders deducted	pounds	29,948,996
Duty—pounds raised 1 foot high with 100 pounds of coal	do	20,644,546
Water pumped	gallons	4,405,699,414
Average height to which water was raised	feet	168.27
Cost of each 1,000 gallons pumped	cents	4.079
Receipts for each 1,000 gallons pumped	do	6.606
Net gain on each 1,000 gallons pumped	do	2.527
Total expenses of operating the works		$179,729 56
Total revenue of the works		$291,047 95
Net earnings		$111,318 39

The original cost of the engines was $40,000.

The cost of the works originally amounted to $700,358 50, divided as shown in the accompanying statement:

Receipts and disbursements for the ten years ending, and including balance on hand, March 31, 1880.

RECEIPTS.

Received from the city on account of construction		$593,819 32
Received from construction of fire-protection lines, etc	$6,840 65	
Received from construction of domestic-supply lines	22,309 17	
Total construction	29,149 82	
Received from sale of office materials	12 00	
Received from water-rents	250,942 29	
Received from meters and repairs of same	10,943 84	
Total receipts from the operations of the works		291,047 95
		884,867 27

DISBURSEMENTS.

For construction of engines, pumps, boilers, buildings, and foundations	$167,932 10	
For construction of fire-protection lines	382,660 81	
For construction of domestic-supply lines	38,024 62	
For construction of filtering galleries, basins, grounds, and levee	83,460 02	
For construction salaries, stationery, and miscellaneous expenses	28,280 95	
Total construction		700,358 50
For cost of pumping	99,982 77	
For care of basins, grounds, gas, and extraordinary repairs	10,413 08	
Total cost of pumping service	110,395 85	
For total cost of hydrant service, including wages, repairs, etc	26,765 94	
For total office expenses, including salaries, etc	29,871 47	
Actual running expenses and repairs	167,033 26	
For return water-rents	751 25	
For meters and repairs of same	11,945 05	
Total operating expenses and repairs		179,729 56
Balance on hand March 31, 1880		4,779 21
		884,867 27

The total net earnings of the works up to March 31, 1880, is $111,318; total operating expenses to same date $179,729; total receipts from operating works to same date, $291,047.

For the year ending March 31, 1880, the cost of maintenance and repairs amounted to $20,669.

For the distribution there are 42 miles of cast-iron pipe, 20, 12, 10, 8, 6, and 4 inches in diameter, the largest being the main from the pump-house. On this system there are 340 Holly patent hydrants, with a few of the Ludlow patent.

Water is supplied to 2,283 water-takers.

An itemized statement of disbursements for a year is annexed, as it may be of value to show the cost of the Holly system in larger cities:

For what purpose.	April, 1879.	May, 1879.	June, 1879.	July, 1879.	August, 1879.	September, 1879.	October, 1879.	November, 1879.	December, 1879.	January, 1880.	February, 1880.	March, 1880.	Totals for the year ending March 31, 1880.
CONSTRUCTION.													
Pumping service.													
Engines, pumps, and boilers	$173 28	$66 84	$2 25	$114 95	.....	.....	.....	.....	.....	$47 56	.....	$12 75	$417 63
Buildings and foundations	.....	.....	.....	.....	.....	.....	.....	.....	$13 08	.....	.....	3 50	16 58
Totals	173 28	66 84	2 25	114 95	.....	.....	.....	.....	13 08	47 56	.....	16 25	434 21
Hydrant service, fire protection.													
Pipe and special castings	283 07	1,445 35	1,065 65	339 94	$2,773 15	$23 67	.....	$21 63	21 69	34 05	$116 98	.....	6,125 18
Lead, hemp, and pipe-laying	895 89	726 75	1,001 79	528 30	334 83	123 62	.....	.....	1 40	93 47	20 25	74 35	3,800 65
Fire hydrants and valves	5 10	500 63	39 24	470 39	12 23	2 80	.....	30 63	.....	.....	573 00	70 20	1,704 22
Totals	1,184 06	2,672 73	2,106 68	1,338 63	3,120 21	150 09	.....	52 26	23 09	127 52	710 23	144 55	11,630 05
Domestic supply.													
Distributing and service lines	118 08	331 46	83 67	321 60	675 50	101 60	$313 83	226 01	58 50	174 17	72 83	102 63	2,579 88
Incidental.													
Filtering galleries and levee	.....	113 85	1 80	534 00	2,476 86	4,465 42	3,241 04	3,253 98	3,287 89	222 04	323 44	3 83	17,924 15
Miscellaneous expenses	.....	.....	250 00	3 00	28 80	.....	.....	.....	.....	15 60	42 50	7 70	347 60
Totals	.....	113 85	251 80	537 00	2,505 66	4,465 42	3,241 04	3,253 98	3,287 89	237 64	365 94	11 53	18,271 75
Total construction	1,475 42	3,184 88	2,444 40	2,312 18	6,301 37	4,717 11	3,554 87	3,532 25	3,382 56	586 89	1,149 00	274 96	32,915 89
OPERATING EXPENSES AND REPAIRS.													
Pumping service.													
Wages of employés	635 33	609 33	617 33	616 83	617 33	626 33	608 58	617 33	908 99	326 67	617 33	610 33	7,411 71
Coal	.....	753 19	8 65	121 51	.....	320 39	53 96	563 38	478 94	7 50	534 60	309 24	3,151 36
Oil and waste	35 35	3 36	52 13	34 57	.....	31 48	.....	42 33	38 61	54 15	3 91	.....	295 89
Ordinary repairs	43 32	26 43	80	35 90	.....	6 95	29 65	4 25	6 00	28 27	25 25	8 98	215 80
Cost of pumping	714 00	1,392 31	678 91	808 81	617 33	985 15	692 19	1,227 29	1,432 54	416 59	1,181 09	928 55	11,074 76
Incidental:													
Filtering-basins, grounds, and extra repairs	40 70	38 50	205 14	114 56	14 76	14 50	.....	10 50	6 00	72 22	35 36	252 44	804 68
Gas	28 64	12 20	15 76	14 32	.....	19 15	.....	34 71	18 81	29 77	18 63	.....	191 99
Miscellaneous expenses	1 50	1 55	.....	143 49	.....	2 43	4 70	12 50	15 20	124 88	12 26	.....	318 51
Totals	70 84	52 25	220 90	272 37	14 76	36 08	4 70	57 71	40 01	226 87	66 25	252 44	1,315 18
Total cost of pumping service	784 84	1,444 56	899 81	1,081 18	632 09	1,021 23	696 89	1,285 00	1,472 55	643 46	1,247 34	1,180 99	12,389 94
Hydrant service.													
Wages of employés	55 56	55 56	55 56	55 56	55 56	55 56	55 56	38 83	95 49	41 67	83 33	83 33	731 57
Tools and repairs	68 73	28 09	70 77	82 28	24 40	67 25	76 84	65 25	116 16	56 15	62 20	48 23	766 35
Hydrant service repairs	124 29	83 65	126 33	137 84	79 96	122 81	132 40	104 08	211 65	97 82	145 53	131 56	1,497 92
Incidental:													
Extraordinary repairs	86 13	25 94	12 38	5 00	61 07	64 77	88 37	26 00	48 27	.....	93 02	53 77	564 72
Miscellaneous expenses	50 35	48 60	108 40	109 40	78 35	96 15	93 92	85 00	57 42	36 85	80 00	71 98	916 42
Totals	136 48	74 54	120 78	114 40	139 42	160 92	182 29	111 00	105 69	36 85	173 02	125 75	1,481 14
Total cost of hydrant service	260 77	158 19	247 11	252 24	219 38	283 73	314 69	215 08	317 34	134 67	318 55	257 31	2,979 06
Office expenses.													
Salaries of officers	341 67	316 67	166 67	166 67	116 67	166 67	266 67	166 67	300 00	83 34	151 67	291 67	2,535 04
Books and stationery	.....	4 05	.....	20 00	62 00	6 71	50 00	.....	.....	.....	.....	.....	142 76
Miscellaneous expenses	25 00	25 35	16 00	99 35	494 50	39 12	16 00	16 00	20 00	191 00	22 68	33 12	998 12
Totals	366 67	346 07	182 67	286 02	673 17	212 50	332 67	182 67	320 00	274 34	174 35	324 79	3,675 92
Actual running expenses and repairs	1,412 28	1,948 82	1,329 59	1,619 44	1,524 64	1,517 46	1,344 25	1,682 75	2,109 89	1,052 47	1,740 24	1,763 09	19,044 92
Incidental:													
Return water-rents	.....	1 00	.....	25 40	27 90	.....	.....	.....	.....	5 00	41 70	9 26	110 26
Meters and repairs of same	741 88	89 79	81 57	93 57	79 21	90 13	111 32	54 03	65 08	12 30	23 32	71 68	1,513 88
Total operating expenses and repairs	2,154 16	2,039 61	1,411 16	1,738 41	1,631 75	1,607 59	1,455 57	1,736 78	2,174 97	1,069 77	1,805 26	1,844 03	20,669 06
Total disbursements for the year	3,629 58	5,224 49	3,855 56	4,050 59	7,933 12	6,324 70	5,010 44	5,269 03	5,557 53	1,656 66	2,954 26	2,118 99	53,584 95

The consumption averages from 2,200,000 to 2,500,000 gallons per day, which is derived entirely from the gallery. The cost of said gallery was $14,000. The intention is to continue its extension in proportion to the increase in water consumption until its limit is reached. This gallery system appears to be eminently applicable to cities located on the western plains, where the water may not be contaminated by surface drainage and impurities.

The following analyses are by H. H. Edgerton, of Fort Wayne, Indiana:

Samples taken from—	Free ammonia.	"Albuminoid ammonia."
Scioto river, muddy	0.04	0.38
Scioto river, settled 24 hours	0.04	0.27
Olentangy river, muddy	0.03	0.36
Water-works water, daily supply	0.13	0.10
Driven well near deep basin B	0.04	0.05
Driven well, center of city	*a* 3.00	0.10

a Probably contaminated with urine.

The works are under the supervision of Frank Doherty, superintendent.

An analysis recently made by Curtis C. Howard, of Columbus, of a sample taken from a city hydrant, gives the following results:

	Grains per gallon.
Carbonate of lime	14.09
Sulphate of lime	0.61
Sulphate of magnesia	9.24
Chloride of sodium	0.41
Silica	Trace.
Organic matter	Trace.
Total	24.35

BURLINGTON, IOWA.

Burlington, containing a population of 19,450, is situated on the west bank of the Mississippi river, and is of considerable commercial importance as a railroad center. It is situated partly on a bluff and partly on ground sharply rising from the river, making the topography very irregular. The streets are laid out rectangularly.

Water was introduced by a private corporation in 1878, and is derived by direct pumping from the Mississippi river. The financial plan followed out in the management of these water-works is worthy of notice. The city guarantees 6 per cent. interest on $200,000 worth of bonds, and levies a tax of 5 mills on all property within 1,000 feet of the mains. It also reserves the privilege of buying the works at the end of 25 years.

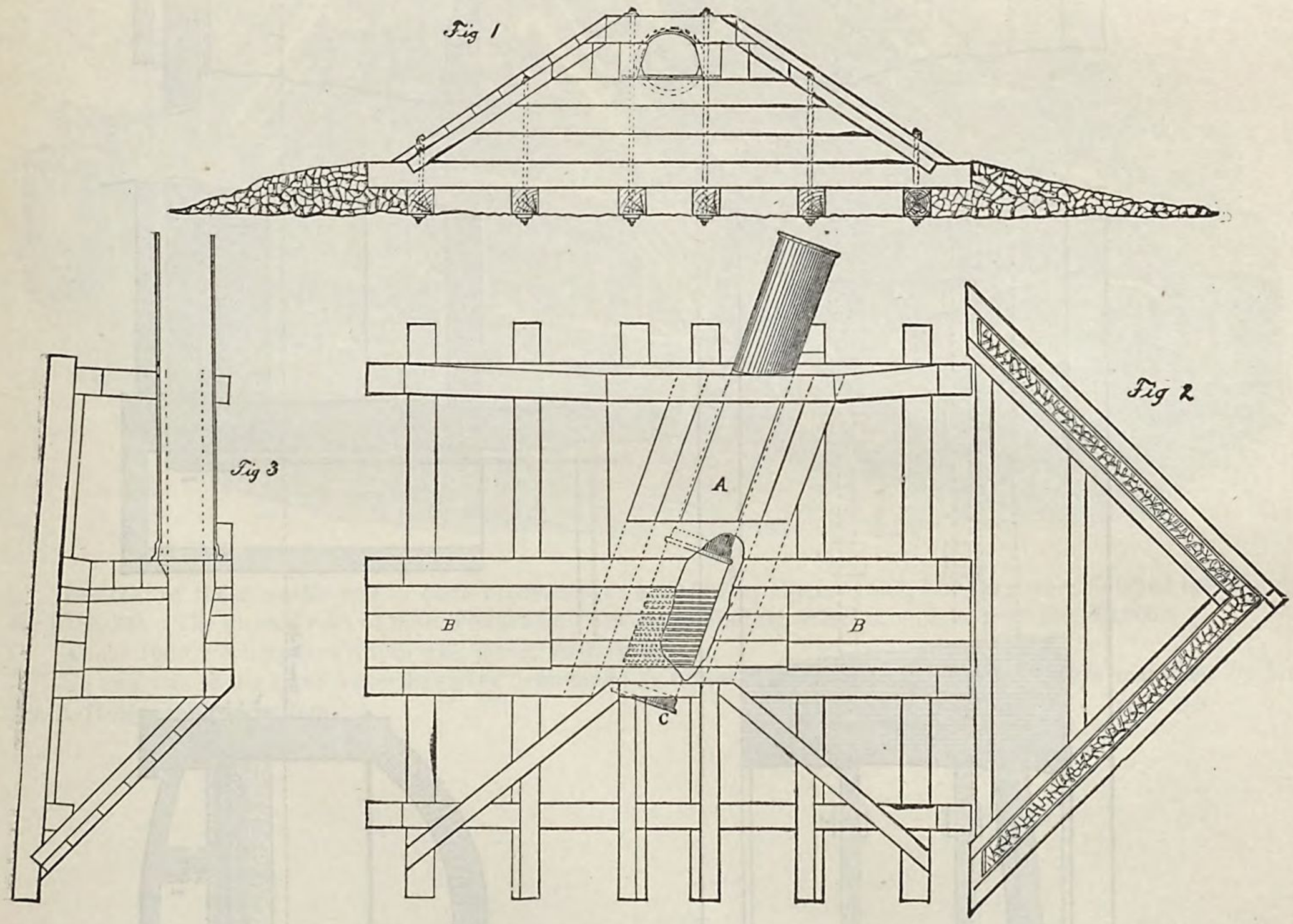
The system in use is known as a pure type of the Holly. At a point in the river 250 feet from the shore a crib is sunk, the construction of which is illustrated in the cut on page 51. Fig. 1 shows the end elevation of this crib. It is constructed of a frame of timber held in place by stones. As originally constructed, the inlet-pipe shown at A, Fig. 2, extended only to the side of the sluice-way B, B, but on one occasion the sluice-way became partially obstructed with sand, which the force of the current was unable to remove; it was therefore found necessary to extend it across the sluice-way to C.

The illustrations on page 52 show the filtering gallery. The inlet-pipe is 24 inches in diameter, and extends to the screen-chamber at D, a distance of 375 feet. This chamber is at the eastern end of the gallery, the western end of which is the wall of the pump-house. The gallery is 120 feet long by 20 feet wide by 18 feet deep. It is an arched chamber of masonry, the summit or crown of which is 14 feet below the surface of the ground at the pump-house. The foundations were laid in a blue-clay rock, which softens on exposure to the air. On this a reversed arch of stone, 12 inches thick, was built, and on this, as a flooring, stone blocks 24 inches cube and 8½ feet apart were laid as shown at E, E. Timbers 12 by 16 inches were laid longitudinally of the gallery, as shown at F, F. These serve as a foundation for a flooring, shown at G, constructed of boards 4 inches wide by 2 inches thick and laid 1 inch apart. The filtering material is laid upon this, and consists of a layer of 6 inches of coarse gravel; on this is 6 inches of fine gravel; the next layer is 12 inches of coarse sand; and the top and last layer is 2 feet of fine sand. The surface of the latter is 2 feet below low-water level. The depth of water above the filtering materials varies, therefore, from 2 feet to 21 feet, according to the stage of the river. The sides of the gallery are built of limestone 30 inches thick, surmounted by an arch of 4 feet rise and 24 inches thick.

From the western end of the gallery, at H, the pump-well, a 24-inch pipe runs under the flooring of the gallery and connects the screen-chamber with the well direct, enabling the water to be taken direct from the river without

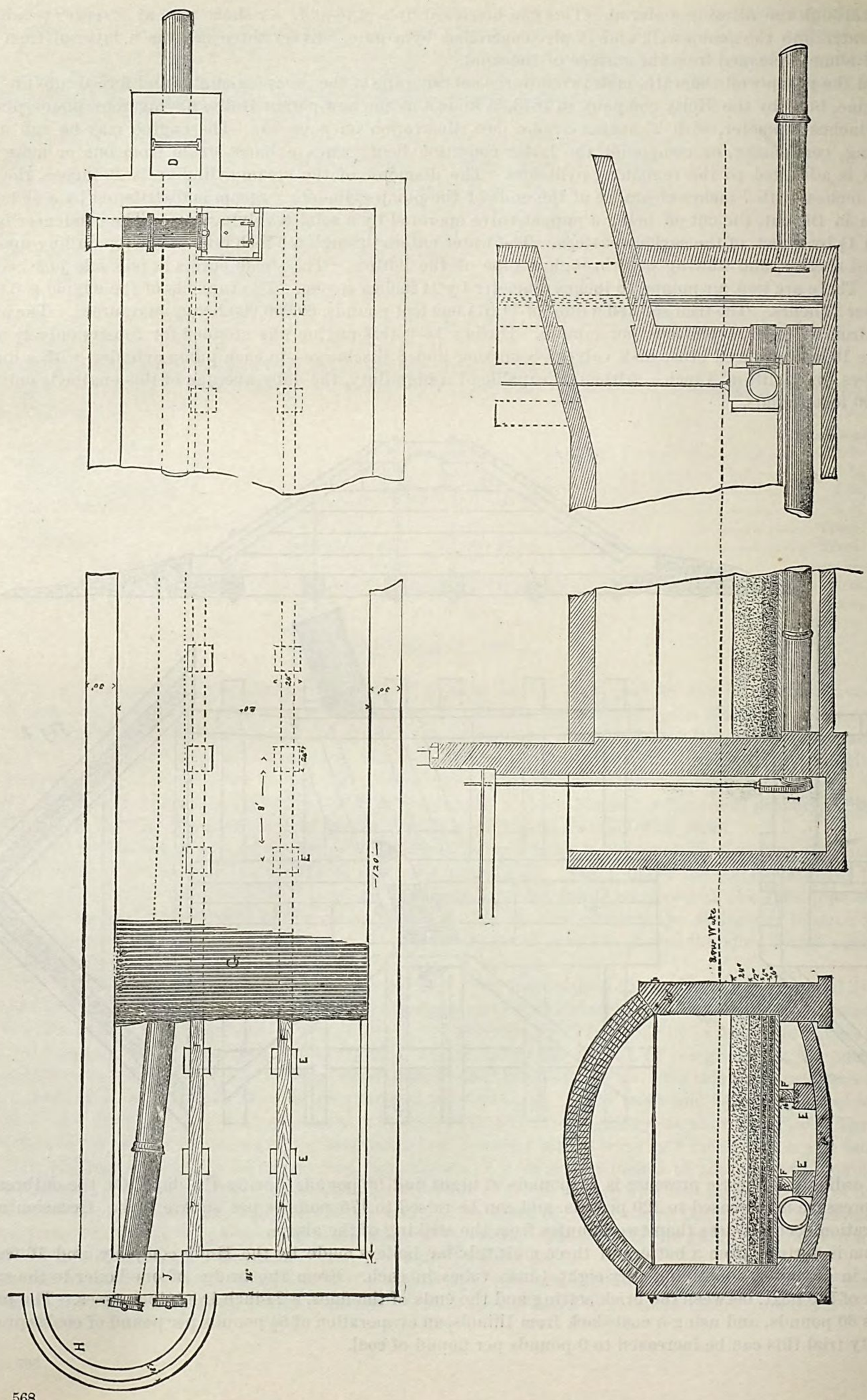
passing through the filtering material. This can be closed by a gate at I. A short pipe at J serves to admit the filtered water into the pump-well, and is also controlled by a gate. Every three months a layer of from 4 to 6 inches of slime is cleaned from the surface of the sand.

From the pump-well the water is drawn into the suction-pipe of the pumping-engine and forced into the mains. This engine, built by the Holly company in 1878, is known as the new-patent Holly, having four piston-plungers, each 10 inches diameter, with 27 inches stroke (see illustration on page 53). The engine may be run as non-condensing, condensing, or compound, the latter condition being when exhaust-steam from one or more of the cylinders is admitted to the remaining cylinders. The diameter of the steam-cylinders is 19 inches, the stroke being 27 inches, with 7 inches clearance at the ends of the pump-cylinders. Steam is distributed by a slide-valve, as shown in the cut, the cut-off being a puppet-valve operated by a solid revolving cam. The condenser is 5 feet high and 4½ by 2 feet, of the surface pattern. The water enters through a 6-inch inlet at the top, falling upon a set of inclined shelves, and flowing out through a pipe at the bottom. The steam enters at one side just below the middle. There are two air-pumps 18 inches diameter by 24 inches stroke. The capacity of the engine is 3,000,000 gallons per 24 hours. The trial showed a duty of 71,514,000 foot-pounds, 60,000,000 being guaranteed. The average speed is from 12 to 15 revolutions per minute. During 1880 this engine was stopped for repairs only 1⅕ minute. There are 16 leather-faced brass disk valves—8 suction and 8 discharge—in each pump-cylinder, with a diameter of 6 inches and a lift of ⅜ inch. Although capable of a high duty, the daily average of this engine is only about 36,260,000 foot-pounds.

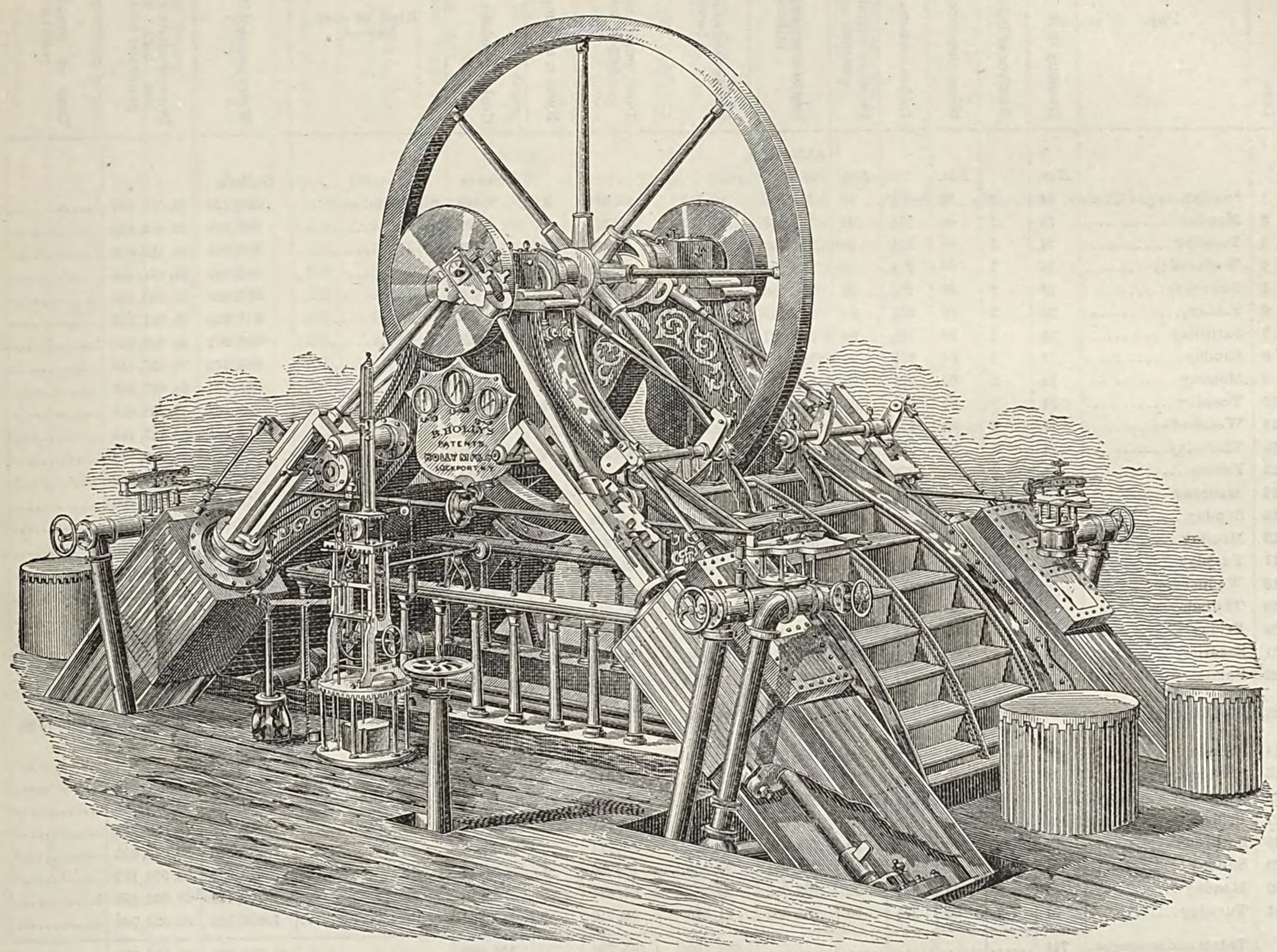


The ordinary domestic pressure is 85 pounds at night and 90 pounds during the day. On the outbreak of a fire the pressure is increased to 120 pounds, and can be raised to 175 pounds per square inch. Occasion arising, this operation occupied less than two minutes from the striking of the alarm.

Steam is derived from a battery of three multitubular boilers made by the Holly company, and 16 feet long by 5 feet in diameter, containing fifty-eight 4-inch tubes in each. From the bridge of one boiler to the space at the back of the next, between the brick setting and the ends of the flues, a 24-inch iron pipe passes. The pressure averages 60 pounds, and using a coal-slack from Illinois, an evaporation of 5½ pounds per pound of coal is produced. On a duty trial this can be increased to 9 pounds per pound of coal.


D
E
G
F
J
I
H
Bear Wake

The work at present performed by this engine consists in pumping daily about 590,000 gallons for the use of 811 water-takers. A system of mains of cast iron $1\frac{4106}{5280}$ mile long serves to distribute it. In addition there is $1\frac{4246}{5280}$ mile of wrought-iron pipe, varying from $\frac{3}{4}$ to $1\frac{1}{2}$ inch diameter, used as service-mains. The mains are of 24, 16, 12, 10, 8, 6, and 4 inches diameter, and Holly's patent hydrants to the number of 202 are attached to them.



The cost of these works was to have amounted to $200,000 by the contract, but they were finished completely for $185,000. The annual cost of maintenance and repairs, including salaries, etc., is, for 1880, $6,000.

About 100 Crown meters are in use, giving satisfaction.

No analysis of the river water has ever been made as taken from this point. The works are managed by Mr. Ira A Holly, superintendent.

Burlington water-works—Record of engines and pumps,

Date.	Day.	Running time.	Number of boiler.	Steam pressure.	Inches vacuum.	Pressure maintained for domestic service.	Register reading of revolutions.	Revolutions of engines for 24 hours.	Total pump revolutions per 24 hours.	Number of pumps running.	Coal burned for 24 hours.	Kind of coal burned.	Water pumped in 24 hours.	Duty—pounds raised one foot high with 100 pounds of coal.	Time of fire-alarm received.
							a 163, 595								
		Hrs.		*Lbs.*		*Lbs.*					*Pounds.*		*Gallons.*		
1	Sunday	24	2	60	27½	90	180, 330	16, 735	33, 470	2	3, 443	Slack and nut	602, 460	33, 512, 384	
2	Monday	24	2	60	27½	90	198, 500	18, 170	46, 275	⅔	4, 737	do	832, 950	33, 824, 416	
3	Tuesday	24	2	60	27½	90	217, 542	19, 042	46, 080	⅔	4, 677	do	829, 440	34, 113, 979	
4	Wednesday	24	2	60	27½	90	236, 300	18, 758	46, 669	⅔	4, 715	do	840, 042	34, 271, 575	
5	Thursday	24	2	60	27½	90	255, 090	18, 790	45, 546	⅔	4, 404	do	819, 828	35, 965, 206	
6	Friday	24	2	60	27½	90	275, 275	20, 185	50, 946	⅔	4, 826	do	917, 028	36, 711, 522	
7	Saturday	24	2	60	27½	90	295, 121	19, 845	49, 999	⅔	4, 938	do	899, 982	35, 009, 421	
8	Sunday	24	2	60	27½	90	313, 523	18, 402	36, 804	2	3, 545	do	662, 472	36, 258, 410	
9	Monday	24	2	60	27½	90	332, 572	19, 049	48, 063	⅔	4, 862	do	865, 134	34, 527, 067	
10	Tuesday	24	2	60	27½	90	351, 405	18, 833	47, 676	⅔	4, 352	do	858, 168	38, 262, 619	
11	Wednesday	24	2	60	27½	90	370, 840	19, 435	49, 883	⅔	5, 423	do	897, 894	32, 127, 485	
12	Thursday	24	3	60	27½	90	390, 250	19, 410	48, 215	⅔	4, 683	do	867, 870	35, 960, 173	
13	Friday	24	3	60	27½	90	410, 225	19, 975	51, 404	⅔	4, 943	do	925, 272	36, 164, 869	
14	Saturday	24	3	60	27½	60	429, 800	19, 575	50, 609	⅔	4, 736	do	910, 962	37, 161, 709	
15	Sunday	24	3	60	27	60	445, 851	16, 051	38, 998	⅔	3, 814	do	701, 964	35, 558, 323	
16	Monday	24	3	60	27	90	466, 050	20, 199	52, 848	⅔	4, 980	do	951, 264	36, 904, 458	
17	Tuesday	24	3	60	27	90	485, 745	19, 695	51, 404	⅔	4, 713	do	925, 272	37, 929, 673	
18	Wednesday	24	3	60	27	90	506, 107	20, 362	52, 888	⅔	4, 880	do	951, 984	37, 689, 202	
19	Thursday	24	3	60	27½	90	526, 195	20, 088	53, 531	⅔	4, 984	do	963, 558	37, 351, 405	
20	Friday	24	3	60	27½	90	548, 084	21, 889	56, 546	⅔	5, 430	do	1, 017, 828	36, 214, 432	
21	Saturday	24	3	60	27½	90	570, 720	22, 636	60, 055	⅔	5, 799	do	1, 080, 990	36, 014, 359	
22	Sunday	24	3	60	27½	90	589, 685	18, 965	46, 128	⅔	4, 581	do	830, 304	35, 017, 405	
23	Monday	24	3	60	27½	90	609, 771	20, 086	52, 590	⅔	5, 451	do	946, 620	33, 551, 088	11. 40 p. m.
24	Tuesday	24	3	60	27½	90	630, 221	20, 450	53, 328	⅔	5, 269	do	959, 904	35, 197, 087	
25	Wednesday	24	3	60	27½	90	652, 030	21, 809	59, 078	⅔	5, 831	do	1, 063, 404	35, 387, 225	
26	Thursday	24	3	60	27½	90	675, 541	23, 511	64, 683	⅔	6, 038	do	1, 164, 294	37, 416, 298	
27	Friday	24	3	60	27½	90	699, 000	23, 459	65, 221	⅔	5, 990	do	1, 173, 978	38, 029, 831	
28	Saturday	24	3	60	27½	90	722, 695	33, 695	65, 212	⅔	5, 986	do	1, 173, 816	38, 049, 992	
29	Sunday	24	3	60	27½	90	742, 951	20, 256	51, 296	⅔	5, 336	do	923, 328	33, 576, 192	
30	Monday	24	2	60	27½	90	765, 685	22, 734	61, 635	⅔	5, 716	do	1, 109, 430	37, 824, 683	
31	Tuesday	24	2	60	27½	90	787, 355	21, 670	58, 710	⅔	5, 880	do	1, 056, 780	35, 024, 708	
	Totals and averages.	744						623, 760	1, 595, 790		154, 962		28, 724, 220	35, 812, 130	

a State of register on April 30, 1881.

service, and duty, for the month ending May 31, 1881.

Water-pressure during fire.	End of fire-pressure.	Revolutions of engines during fire.	Lift of pumps.	Height of column of water.	Fuel consumed for each 1,000,000 gallons pumped.	Cost of fuel consumed for each 1,000,000 gallons pumped.	Meter reading of feed-water.	Water evaporated per each pound of fuel consumed.	Machine-oil used.	Cylinder-oil used.	Ashes and cinders left.	Waste and rags used.	Remarks.
							a 259,493						
			Feet.	*Feet.*	*Pounds.*			*Pounds.*	*Galls.*	*Galls.*	*Pounds.*	*Pounds.*	
.....	.....	.....	21.50	228	5,714	$6 14	259,973	6.4	.....	.....	517	.....	Slack and nut coal costs $2 15 per ton.
.....	.....	.....	22.00	229	5,687	6 11	260,093	4.5	.....	.....	616	.....	
.....	.....	.....	22.20	229	5,638	6 06	260,393	4.6	.....	.....	618	.....	
.....	.....	.....	22.60	229	5,612	6 03	260,693	4.6	.....	.....	636	.....	
.....	.....	.....	22.11	230	5,371	5 77	260,993	4.9	.....	.....	597	.....	
.....	.....	.....	23.10	230	5,262	6 56	261,293	4.4	.....	.....	607	.....	
.....	.....	.....	23.50	230	5,486	5 89	261,593	4.4	.....	.....	636	.....	
.....	.....	.....	23.80	231	5,351	5 75	261,893	6.2	.....	.....	507	.....	
.....	.....	.....	23.11	231	5,619	6 04	262,193	4.4	.....	.....	579	.....	
.....	.....	.....	24.00	231	5,071	5 45	262,493	4.9	.....	.....	562	.....	
.....	.....	.....	24.00	231	6,039	6 49	262,793	3.6	.....	.....	182	.....	Changed boilers.
.....	.....	.....	23.60	231	5,395	5 79	263,093	4.6	.....	.....	600	.....	
.....	.....	.....	23.00	230	5,342	5 74	263,393	4.4	.....	.....	655	.....	
.....	.....	.....	22.10	230	5,198	5 58	263,693	5.3	.....	.....	1,200	.....	
.....	.....	.....	22.60	230	5,433	5 84	263,993	5.7	.....	.....	545	.....	
.....	.....	.....	22.60	230	5,235	5 62	264,441	6.5	.....	.....	642	.....	
.....	.....	.....	22.60	230	5,093	5 47	264,710	4.1	.....	.....	620	.....	
.....	.....	.....	22.60	230	5,126	5 51	264,820	1.6	.....	.....	617	.....	Packed L. F. pump-piston.
.....	.....	.....	22.20	230	5,172	5 55	265,170	5.1	.....	.....	662	.....	
.....	.....	.....	22.00	230	5,324	5 73	265,520	4.7	.....	.....	776	.....	Packed L. B. pump-piston.
.....	.....	.....	21.80	230	5,364	5 76	265,870	4.4	.....	.....	795	.....	
.....	.....	.....	22.50	230	5,517	5 93	266,220	5.5	.....	.....	583	.....	Fixing leak corner Boundary and Jefferson streets.
130	11.50 p. m.	120	22.90	230	5,758	6 18	266,390	2.2	.....	.....	716	.....	Fire; small frame on Jefferson street, between Eighth and Boundary streets.
.....	.....	.....	23.50	230	5,489	5 90	266,790	5.4	.....	.....	665	.....	
.....	.....	.....	23.10	231	5,483	5 89	267,190	4.9	.....	.....	733	.....	
.....	.....	.....	24.00	231	5,185	5 57	267,590	4.9	.....	.....	920	.....	Thermometer 88° in the shade.
.....	.....	.....	24.40	231	5,102	5 48	267,990	4.8	.....	.....	811	.....	Thermometer 90° in the shade.
.....	.....	.....	24.40	231	5,099	5 48	268,390	5.0	.....	.....	978	.....	Thermometer 94° in the shade.
.....	.....	.....	24.50	231	5,779	6 21	268,790	4.8	.....	.....	193	.....	Changed boilers.
.....	.....	.....	24.10	232	5,152	5 53	269,190	5.1	.....	.....	824	.....	
.....	.....	.....	25.00	232	5,564	5 98	269,590	5.5	.....	.....	1,332	.....	
.....	.....	.....	.....	230	5,394	5 79	b 10,097	4.7	2	4	20,924	20	

a State of meter on April 30, 1881. *b* Cubic feet.

Average amount of water pumped per 24 hours, in gallons, 926,587.7; average amount of coal used per 24 hours, in pounds, 4,998.7; total cost of each 1,000,000 gallons pumped, $69.37 (including construction account); average revolutions per minute of engine, 13.9; pounds of water raised 1 foot high for each pound of coal consumed, 358,110; pounds of water raised 230 feet high for each pound of coal consumed, 1,557.

IRA A. HOLLY,
Superintendent of Water Works.

PEORIA, ILLINOIS.

Peoria contains a population of 29,259, and is situated on the west bank of the Illinois river, 192 miles above its mouth. Its site is an elevated plateau, about 2 miles square, one side sloping down toward the river. The streets are laid out rectangularly.

Water was introduced in 1869 from the Illinois river by pumping direct into the mains; the works are under municipal control. The water is taken from the river, at a point 2 miles northeast of the court-house, by an iron pipe 24 inches in diameter and 300 feet long, the end resting in the channel and protected by a screen. This pipe enters a basin 86 feet long, 20 feet wide, by 32 feet deep, situated alongside the pump-house about 600 feet from the river; this was originally intended for a filtering basin. The basin has perpendicular walls, and the bottom is grouted, cemented, and planked. The pump-well, located 10 feet from it in the engine-house, is 14 feet in diameter and 23 feet deep below the floor, and is connected with it by a masonry conduit 10 feet long. One wall of the engine-house is built upon the south wall of the basin, and the flooring is 9 feet above the level of the top of the basin. The basin was never supplied with filtering material. The pump-house of brick contains four sets of pumping-engines, two Worthington duplex, built in 1881, one Cameron "special", built in 1875 at the same time with a Dean duplex. A set of Holly pumps, operated by a Holly 2-cylinder fly-wheel-engine, built in 1869, was operated five years, and was finally removed in 1879, the whole having cost $48,000.

The Worthington engines have steam-cylinders 25 inches in diameter, pump-cylinders 14 inches in diameter, with a stroke of 24 inches. There are twelve inlet and twelve outlet rubber-disk valves 5 inches in diameter, resting on a sort of gridiron seat and lifting 1¼ inch. The jet-condenser used is 4½ by 1½ feet, and contains three perforated plates 1 foot apart, with a water-inlet at the top 2½ inches in diameter and the steam-pipe 6 inches in diameter for the two cylinders. The air-pumps are 18 inches in diameter with 12 inches stroke. The pumps are run at about 18 double strokes per minute.

The Dean duplex consists of two pumps coupled to the same shaft with two fly-wheels. The steam-cylinders are 24 inches in diameter with 20 inches stroke, the pumps being 14 inches in diameter. They are operated at high pressure. There are two inlet- and two outlet-valves at the end of each cylinder, the pumps being double-acting; they are rubber-disk valves 7½ inches in diameter, with a spiral spring, allowing a lift of 1 inch. The suction- and discharge-pipes are 10 inches in diameter, and the pumps are operated at from 18 to 30 revolutions per minute.

The Cameron "special" is a non-condensing, direct, double-acting pump, with steam-cylinder 24 inches and pump-cylinder 12 inches in diameter, and a stroke of 3 feet, operated at from 4 to 6 revolutions per minute, and contains two inlet and two discharge rubber-faced brass disk valves, 9 inches in diameter with 1 inch lift, with spiral springs. The Dean pump cost $6,000, the Cameron $2,500, and the Worthington $17,800.

There are two batteries of two multitubular boilers each, 16 feet long by 56 inches diameter of shell, containing 50 3¾-inch tubes in each, burning soft coal from local mines at a pressure of 90 pounds. There have never been any duty trials nor tests of evaporation. The original boilers cost $3,600, and a new set recently erected cost $4,300. The capacity of the Dean pump for 24 hours is 2,500,000 gallons; of the Cameron, 1,750,000 gallons; and of the two Worthington, 5,000,000 gallons.

The pressure at the pump-house for domestic purposes is from 55 to 60 pounds, with the exception of a single line of 10-inch main which supplies the "bluff" or high parts of the city, on which line the pressure is 90 pounds. In case of fire this pressure is increased to 150 pounds, and on the main service from 110 to 140 pounds. The city consumption averages 2,000,000 gallons per day distributed to 2,190 takers, through 43 miles of cast-iron mains 4, 6, 8, 10, 12, and 16 inches in diameter, with 263 hydrants, chiefly Holly's patent, with a few of the Matthews patent. The first cost of the water-works was $450,000. The annual expense of maintenance and repairs amounts to $14,000.

The water taken from the river is exceedingly impure, with a disagreeable odor during a large part of the year. In the winter when the river is frozen over the odor seems to be increased, and in the boiler-room any escaping steam develops this to an unbearable degree. It is ascribed to the pollution of the river by Chicago sewerage. The present superintendent is Mr. T. J. Kelley, and the mechanical engineer, Mr. David Nicol.

3.—PUMPING TO STAND-PIPE.

BLOOMINGTON, ILLINOIS.

Bloomington contains a population of 17,180, and is situated 126 miles south-southwest of Chicago and 154 miles from Saint Louis. Its business interests are principally agricultural. Topographically the city is but slightly irregular, and the streets intersect each other at right angles. The city introduced a water-supply in 1875 by pumping to a stand-pipe, the water being derived from a well sunk in sand, loam, and clay soil. The well is situated about 600 feet northwest of the corporation line, in a plat of six acres of land owned by the city, and is 28 feet 5 inches deep by 40 feet internal diameter. The first 5 feet was loam clay, and the remaining depth was sand and gravel; underlying this is 7 feet of blue clay with a substratum of fine sand. The latter, containing a strong vein of water, was brought into communication with the main part of the well above by a pipe 18 inches in diameter and 9 feet long, the top extending 3 feet above the bottom of the well. The average depth of water in the well is 14 feet, and the supply, 2,714,000 gallons per day. The well is lined with brick-work 12 inches thick. It was sunk on an iron shoe, tied to the brick-work by vertical iron rods. The brick-work was built up in courses as the shoe was sunk. The well is covered by a frame roofing, and is situated a few feet back of the engine-house. The latter is 28 by 28 feet, with a boiler-room 28 by 44 feet, and the coal-room 20 feet square. A stack in the latter is 65 feet high by 4 feet interior diameter, brick-work 2 feet thick.

A Worthington duplex pump of 1,000,000 gallons daily capacity, erected in 1875 with the works, is run at high pressure, and has steam-cylinders 20 inches in diameter, pump-plungers 12 inches in diameter, and a stroke of 14 inches. It is operated at an average of 44 double strokes per minute during 18 hours per day. No duty-trial has ever been made. Each pump-cylinder contains 22 inlet and 22 discharge rubber disk valves 3 inches in diameter. Steam is supplied by two boilers, one a multitubular, containing forty-four 3-inch tubes, and 16 feet long by 5 inches diameter of shell. The other is 22 feet long by 5 feet in diameter, and contains five flues, three of which are 10 inches and two 12 inches in diameter. They are run at 70 pounds pressure with Illinois soft coal mined in the vicinity. Their evaporation is unknown. The engine cost $3,300. It is to be assisted by a Blake pump placed near it, and having a 30-inch steam- and 15-inch pump-cylinder with a 24-inch stroke.

From the engine-house the water is forced through 600 feet of 10-inch cast-iron main into the stand-pipe. This consists of a cylinder of wrought iron 8 feet in diameter and 200 feet high, encased in a brick tower, with walls 7 feet thick at base by 12 inches thick at the top. A spiral staircase encircles the pipe. There is one inlet and one outlet, each 16 inches in diameter, connected with the force-main in the adjacent street by two short branches furnished with valves, by which the pipe can be shut off from the system and direct pressure exerted. From here the water flows by gravity through a little over 10 miles of cast-iron mains. A statement is made by the superintendent in the annual report of 1877, to the effect that the net cost for running the water-works by direct pressure before the introduction of the stand-pipe, for the month of January, 1876, was $479 50, while the average monthly cost for 1877 was only $168.

The distributing mains are of 10, 8, 6, and 4 inches in diameter, the greatest length being of 4 and 6 inches. There are 124 hydrants, the majority of the Matthews patent, with a few of Chapman's and Flowers. The average consumption is estimated at 300,000 gallons per day, distributed among 515 takers.

The first cost of the works is given at $75,000. Of this amount the items are somewhat as follows:

Engines	$3,300 00
Buildings at the pump-station	2,850 00
Stand-pipe	28,579 00

The remainder was expended for the ground on which the buildings are located, the force- and distributing-mains, boilers, well, etc. The total cost to date amounts to $113,000. The annual repair and maintenance cost for 1880 was $5,000.

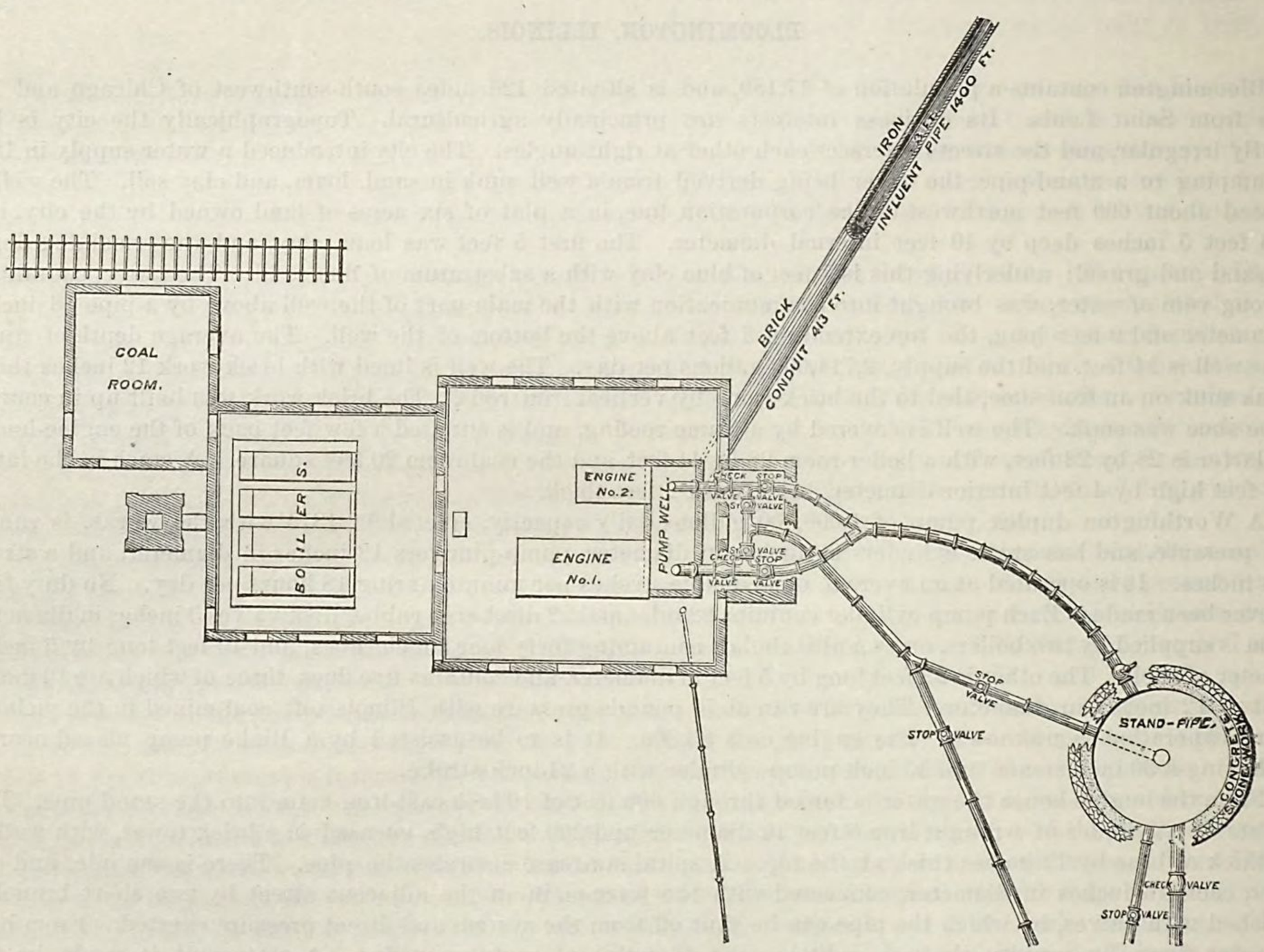
The head of water on the mains varies from 75 to 100 pounds with a full stand-pipe. An analysis made by Dr. D. S. Dyson gave the following results:

	Grains per gallon.
Total solids	76
Carbonate of magnesia	24
Carbonate of lime	8
Carbonate of iron	12
Chloride of sodium	Trace
Sulphur by precipitation	32

The control of the works is in the hands of M. X. Chuse, superintendent.

SANDUSKY, OHIO.

Sandusky contains a population of 15,838, and is located on a bay of the same name of lake Erie, its site sloping southward from the bay. The interests of the city are chiefly commercial.



SANDUSKY WATER-WORKS PUMPING STATION.

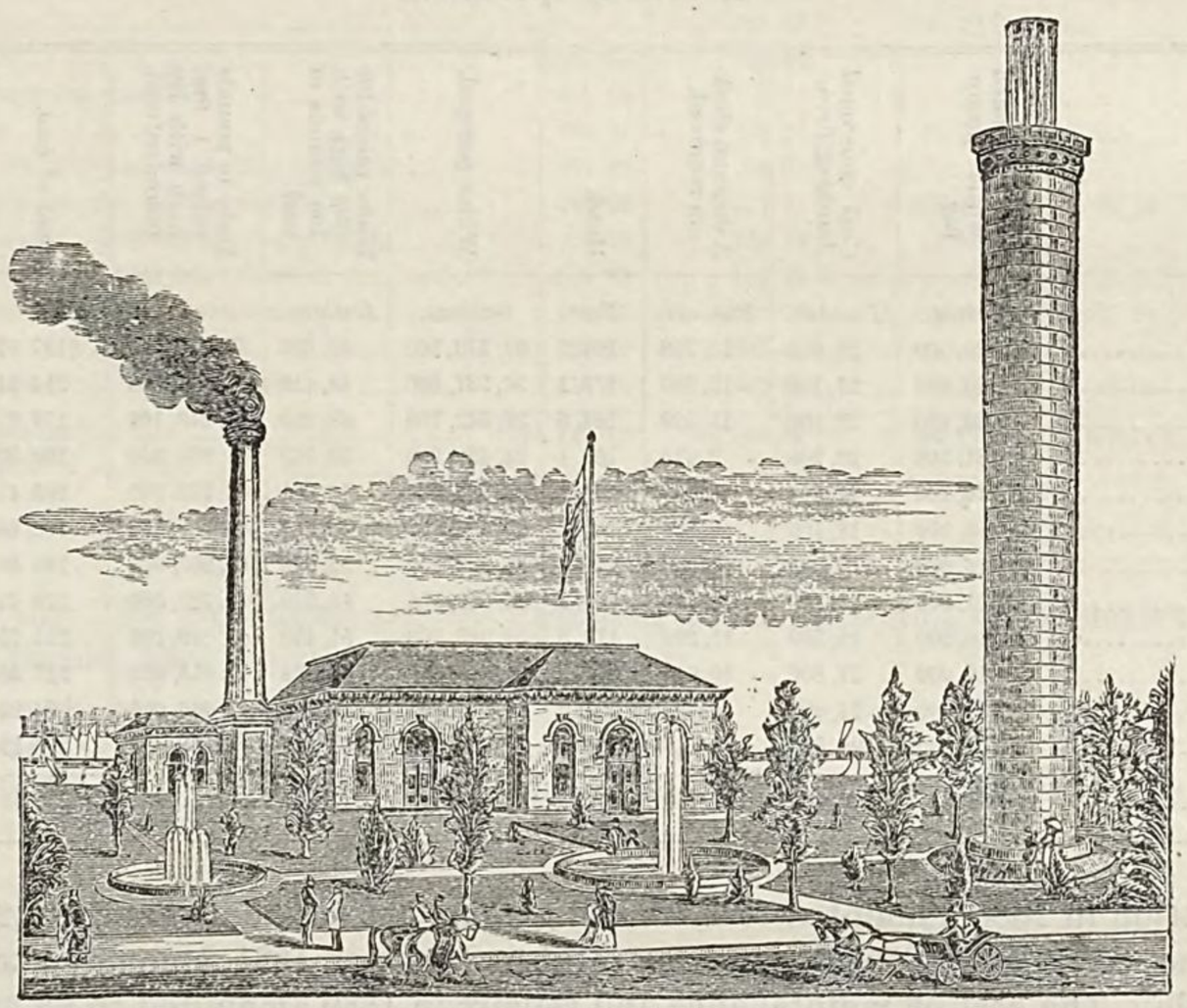
Water was introduced in 1876 by the city authorities, and is derived by pumping from Sandusky bay. By an arrangement of stop-gates in the mains the pumping is either direct into the mains, to the stand-pipe, or a combination of both of these systems. The crib from which the water is taken is situated 1,800 feet from the shore-line of the bay. It is octagonal in plan, with an inner diameter of 25 and an outer of 45 feet. Two rows of sheet-piling, driven to rock-bottom, are 8 feet apart, and the intervening space is filled with broken sandstone. Through this the water of the bay passes to reach the mouth of the inlet-pipe, as in the case of Toledo. The top of the crib is 6 feet above high-water level in the bay.

The inlet-pipe is of wrought iron, 3 feet in diameter, 1,800 feet long, and buried in water 12 feet deep. The crib end is turned vertically, and its mouth protected by a perforated copper-plate screen. The joints are made with a half-sleeve riveted to the end of each section, with flanges which are riveted to each other. From the termination of this pipe on the shore a brick conduit, 413 feet long and 3 feet in diameter, leads the water to the pump-well of the engine-house. A stop-gate is arranged in this conduit near the well, in order to cut it off if it

becomes necessary to empty the well. The latter is an excavation in the rock 22 by 8 feet by 21½ feet deep, lined with brick throughout. Above this is an engine-house, of bluestone, 50 by 50 feet, with a height of 28 feet; the boiler-house connected therewith is 40 by 40 by 28 feet, flagged, having a chimney-stack 100 feet high and 3 by 3 feet on the inside.

The pumping machinery consists of two sets of Worthington engines, one a duplex compound and the other a high-pressure, both built in 1876, the former having a capacity of 3,000,000 and the latter of 2,000,000 gallons per day. The duplex engine has a low-pressure steam-cylinder of 43$\frac{3}{10}$ inches diameter, high-pressure cylinder of 25 inches diameter, pump-plungers 17½ inches diameter, and a stroke of 3 feet. Average engine duty in 1880, 43,000,000 foot-pounds. The high-pressure engine has steam-cylinders of 24 inches diameter, pump-plungers of 16 inches diameter, and a stroke of 26 inches. Average speed, 34 double strokes per minute. The total cost of these engines was $32,500, and the repairs to date have amounted to less than $100, although run during twelve hours per day all the year round.

From the pumps a 20-inch cast-iron force-main connects with the stand-pipe, 70 feet distant. The head on the pumps is equivalent to 180 feet for domestic and 229 feet for fire pressure.



SANDUSKY WATER-WORKS.

The stand-pipe is unique. It consists of a shell of wrought steel 180 feet high and 25 feet in diameter, containing an inner column of steel 229 feet high and 3 feet diameter, used as a stand-pipe in case of fire, to give additional head. The outer shell is known as the reservoir, and is leaded into a shoe of cast iron in segments bolted together. Twelve iron 1½-inch rods fastened to the second course of the outer shell have their lower ends leaded into the rock 8 feet below ground and spread by wedges. The foundation of the whole structure is upon limestone-rock, and was built by J. & T. McGregor, of Detroit. The metal has a tested strength of 67,000 to 87,000 pounds per square inch. Valves regulating the admission of water to the inner or outer shell are controlled by gearing and rods operated from the engine-house.

From the stand-pipe the water is distributed through 108,126 feet of cast-iron pipe of the following lengths and sizes:

	Linear feet.
20-inch	4,370.8
16-inch	3,263.7
12-inch	10,989.0
8-inch	32,932.4
6-inch	48,430.8
4-inch	5,078.7
3-inch	601.0
2- and 1½-inch	2,460.0
Total	108,126.4

Attached to these there are 47 Lowry and 99 Matthews hydrants and 141 gates. The performance of the engines for the year 1880 and the relative cost of pumping for the last four years are given in annexed tables:

Cost of pumping and amount received from 1,000 *gallons.*

Year.	Cost of pumping each 1,000 gallons.	Amount received in water-rents for each 1,000 gallons.	Cost of pumping 1,000,000 gallons 100 feet high.
	Cents.	*Cents.*	
1877	2.29	4.17	$14 80
1878	1.83	4.12	11 25
1879	1.19	2.94	8 33
1880	1.17	2.77	7 00

Details of operation.

Months, 1880.	Coal consumed while pumping.	Coal consumed banking fires.	Ashes and clinkers removed.	Head.	Water pumped.	Water raised 100 feet high with 100 pounds of coal.	Duty in pounds raised 1 foot high with 100 pounds of coal.	Cost of coal.	Salaries of engineers and firemen.	Cost of oil, gas, packing, waste, etc.	Total cost.
	Pounds.	*Pounds.*	*Pounds.*	*Feet.*	*Gallons.*	*Gallons.*					
January	120,500	28,600	15,258	164.3	31,313,360	42,695	35,579,166	$197 83	$159 03	$22 73	$379 59
February	106,600	25,100	12,590	170.1	30,337,800	48,410	40,341,666	214 11	160 83	23 31	398 25
March	90,400	23,500	11,229	164.5	26,542,700	48,299	40,249,166	177 67	160 83	23 55	362 05
April	81,500	22,200	9,416	168.1	24,420,250	50,369	41,974,366	162 33	160 83	22 13	345 29
May	110,700	24,200	9,105	166.1	33,784,200	50,691	42,242,500	205 43	160 83	19 90	386 16
June	113,900	18,100	6,320	166.2	33,420,600	48,767	40,639,166	198 64	160 83	19 96	379 43
July	116,000	13,200	3,968	169.8	35,992,550	52,686	43,905,000	184 80	160 83	20 11	365 74
August	121,300	19,400	11,720	169.2	34,552,150	48,219	40,182,500	218 63	160 84	21 75	401 22
September	110,500	19,500	11,809	170.2	33,383,300	51,419	42,849,166	211 25	160 83	22 50	394 58
October	116,900	21,800	10,648	170.2	34,300,300	49,938	41,615,000	227 60	160 83	23 36	411 79
November	153,500	24,800	14,444	167.0	45,770,800	49,796	41,496,666	294 20	172 83	26 93	493 96
December	156,530	25,800	16,116	170.2	47,936,800	52,123	43,435,833	296 29	200 83	28 54	525 66
Total	1,398,330	266,200	132,633	.....	411,754,810	.....	.....	2,588 78	1,980 17	274 77	4,843 72

The total consumption in 1880 amounted to 1,128,300 gallons per day, delivered to 1,200 consumers.

The first cost of the works was $375,000, and the total to January, 1881, amounted to $387,189 76. The items may be seen in the table. The cost of maintenance and repairs in 1880 amounted to $8,322 50, as follows:

Paid for fuel (including $11 75 for office)	$2,600 53
Gas, waste, ice, and oil (including gas and ice for office)	227 75
Salaries of superintendent, engineers, and firemen	3,190 09
Salaries of secretary and trustees	1,099 92
Office rent, expense of printing, stationery, etc	305 16
Tools, hose, etc	96 26
Sundries, extra labor, drayage, freight, papering and painting office, etc	242 12
Repairs on valves	59 67
Repairs on hydrants	56 91
Repairs on pipe-line	22 31
Repairs on influent-pipe	319 84
Repairs on stand-pipe	27 25
Repairs on engine-house	16 85
Repairs on boilers and engine	57 84

The receipts for water-rents in 1880 were $11,141.

Construction account.

Object of expenditures.	Amount paid prior to December 30, 1876.	Amount paid in the year 1877.	Amount paid in the year 1878.	Amount paid in the year 1879.	Total cost.
Water-pipes	$106,827 27	$1,530 95	$98 86	$3,913 33	$112,370 41
Pipe-laying	88,202 30	3,248 58	43 68	1,634 08	93,128 64
Stand-pipe	20,981 87	26,046 20	1,079 98	.....	48,108 05
Stand-pipe connections	8,098 70	.....	.....	.....	8,098 70
Engine, boilers, etc	5,543 47	27,137 15	14 00	.....	32,694 62
Influent-pipe	19,819 62	12 50	.....	.....	19,832 12
Bay crib	3,753 03	.....	.....	.....	3,753 03
Pump-well	1,462 28	2 65	.....	.....	1,464 93
Hydrants	9,135 15	579 50	.....	396 48	10,111 13
Gates and valves	7,660 12	398 09	13 50	197 99	8,269 70
Engine-house	11,111 54	2,056 91	.....	.....	13,168 45
Dwelling-house	.....	513 50	757 62	.....	1,271 12
Smoke-stack	2,081 45	10 00	.....	.....	2,091 45
Traveling and telegraph expenses	610 04	8 61	.....	.....	618 65
Implements and tools	704 87	172 23	34 02	.....	911 12
Office and engine-house furniture, including iron safe	477 20	69 63	.....	.....	546 83
Filling and ornamenting engine-house grounds	769 62	1,177 71	1,061 16	28 50	3,036 99
Office expenses, stationery, advertising, and printing	1,136 16	178 28	12 40	.....	1,326 82
Sundries and incidentals, and analysis of water	580 68	288 03	.....	.....	868 71
Ferrules, stops, boxes, and service connection	2,034 65	5,099 76	1,255 70	1,057 72	9,447 83
Officers' salaries	3,733 99	525 00	.....	.....	4,258 99
Engineering, superintendence, and inspection	7,016 45	500 00	.....	166 64	7,683 09
Total amount paid out	301,740 46	69,555 26	4,356 92	7,408 74	383,061 38
Amount paid out in 1880	.....	.....	.....	.....	4,128 38
Total	.....	.....	.....	.....	387,189 76

The water taken from the lake was analyzed by Professor S. H. Douglas, of Michigan university, in 1876, when the lake was slightly turbid, and the result is given below:

Appearance perfectly clear and limpid after filtration.

Matter (inorganic) held in suspension rendered it slightly turbid and of a yellowish tint.

Hardness, on Clark's scale, 1° to 16° (16° being the hardest). Before boiling, 4°. After boiling, 2.5°. Oxygen absorbed by organic matter from permanganate of potassium, 65.

Constituents.	Grains per U. S. gallon, 58,328.889 grains.	Parts per 1,000,000.
Chloride of sodium	0.265688	4.5490
Sulphate of sodium	0.883088	15.1090
Sulphate of calcium	0.739536	12.6720
Carbonate of calcium	4.460140	76.3350
Carbonate of magnesium	1.238134	21.1860
Silica	0.321248	5.5000
Iron (ferric oxide)	0.105094	1.8000
Oxygen displaced	0.036518	0.6281
Total	8.049440	137.7800
Total matter held in suspension, separated by filtration	0.803271	13.7500
Total held in solution	7.246169	124.0300
Earthy carbonates	5.698274	97.3140

An account of an accident to the inside stand-pipe on October 20, 1878, is thus given in the report for that year:

During a fire on the afternoon of the 20th day of October, the fire pressure-pipe burst at a point 50 feet below top of large tank. The reaction caused by the water escaping through the rupture buckled over the pipe and forced it against the side of the large tank with great violence, breaking it in a second place, bruising and otherwise injuring a section of about 25 feet. When the damaged parts had been removed it was decided to replace with iron of $\frac{1}{4}$ of an inch in thickness, and as the iron of the pipe as originally constructed had a thickness for the first 100 feet of $\frac{1}{4}$ of an inch, and for the second 100 feet, $\frac{3}{16}$ of an inch, it was thought desirable to remove all of the $\frac{3}{16}$-inch iron below the break and substitute $\frac{1}{4}$ inch, which has accordingly been done. As the pipe now stands the shell has a thickness of $\frac{1}{4}$ inch for the first 140 feet, $\frac{3}{16}$ inch for 60 feet, and $\frac{1}{8}$ inch for the remaining 29 feet.

A spiral staircase has recently been built around the outer shell.

A peculiar occurrence is thus mentioned in the report for 1880:

During the month of February, 1880, it was discovered that the water in the pump-well was unusually low, and that the flow of water through the conduit was gradually diminishing, until the 13th of February, when it almost ceased—from no apparent cause, as the valve at the end of the brick conduit was examined and found to be open full head. During the night of the 13th, the difficulty seemed

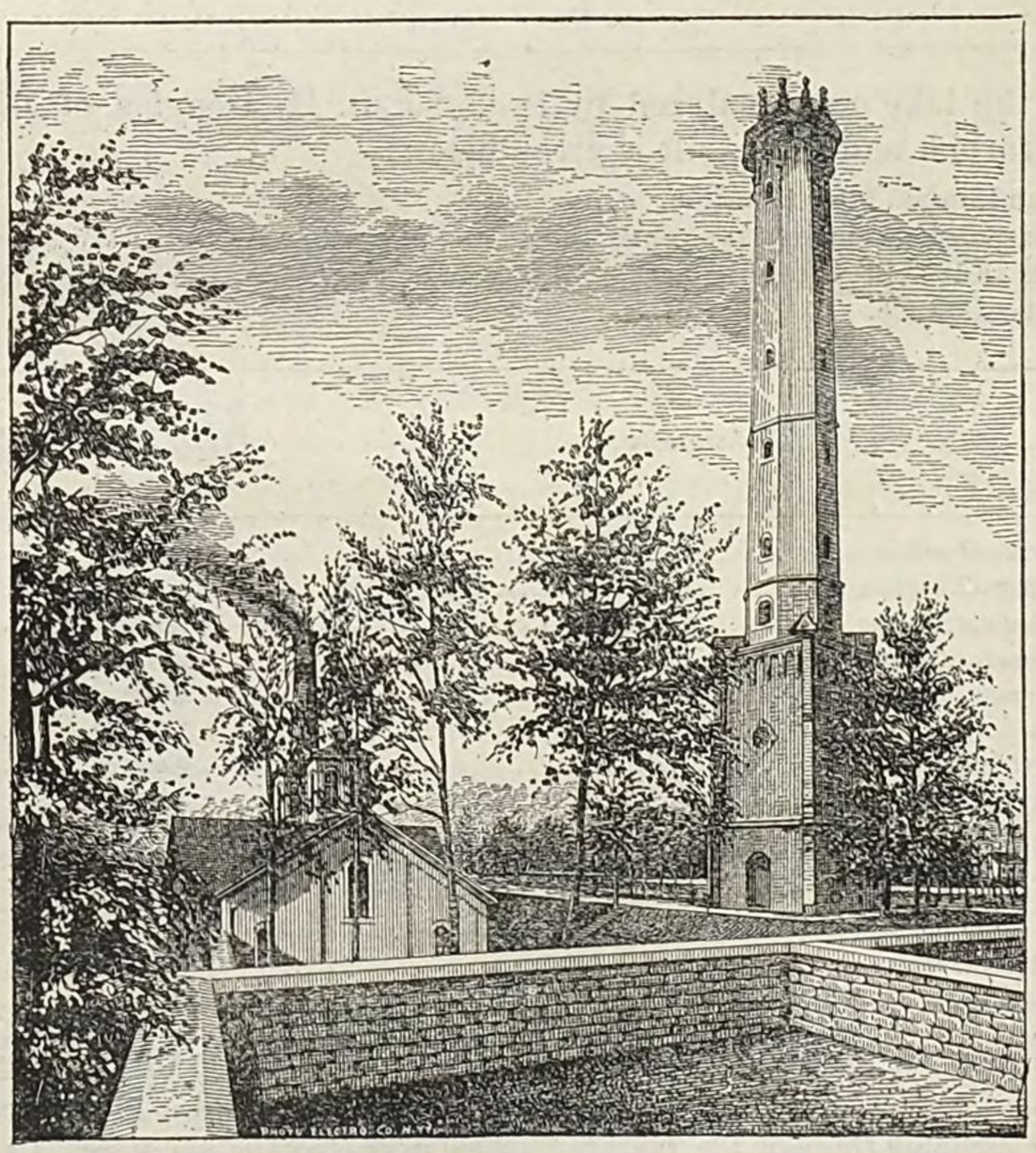
to have been removed and the flow of water was as usual, but very roily and impure. Subsequently it was ascertained that there was a break in the influent pipe near where it joined the brick conduit. It was found that the copper strainer on the end of the influent-pipe inside the bay-crib had become completely enveloped with a peculiar fibrous sediment or fungi, impervious to water, which caused the pipe to rise from its anchorage and separate at a joint near the coffer-dam. This vegetable formation was very tough, impervious to water, and, when dried, was non-combustible.

The works are under the control of a board of three trustees, with a term of office of three years. Erwin Graves is superintendent, and David M. Arndt, secretary.

TOLEDO, OHIO.

Toledo, containing 50,137 inhabitants, is situated on the west bank of the Maumee river 4 miles from lake Erie, and is on comparatively level ground, with streets intersecting each other at right angles. The site was originally two distinct settlements, one of which is somewhat more elevated than the other. It is chiefly a commercial center with considerable manufacturing interests.

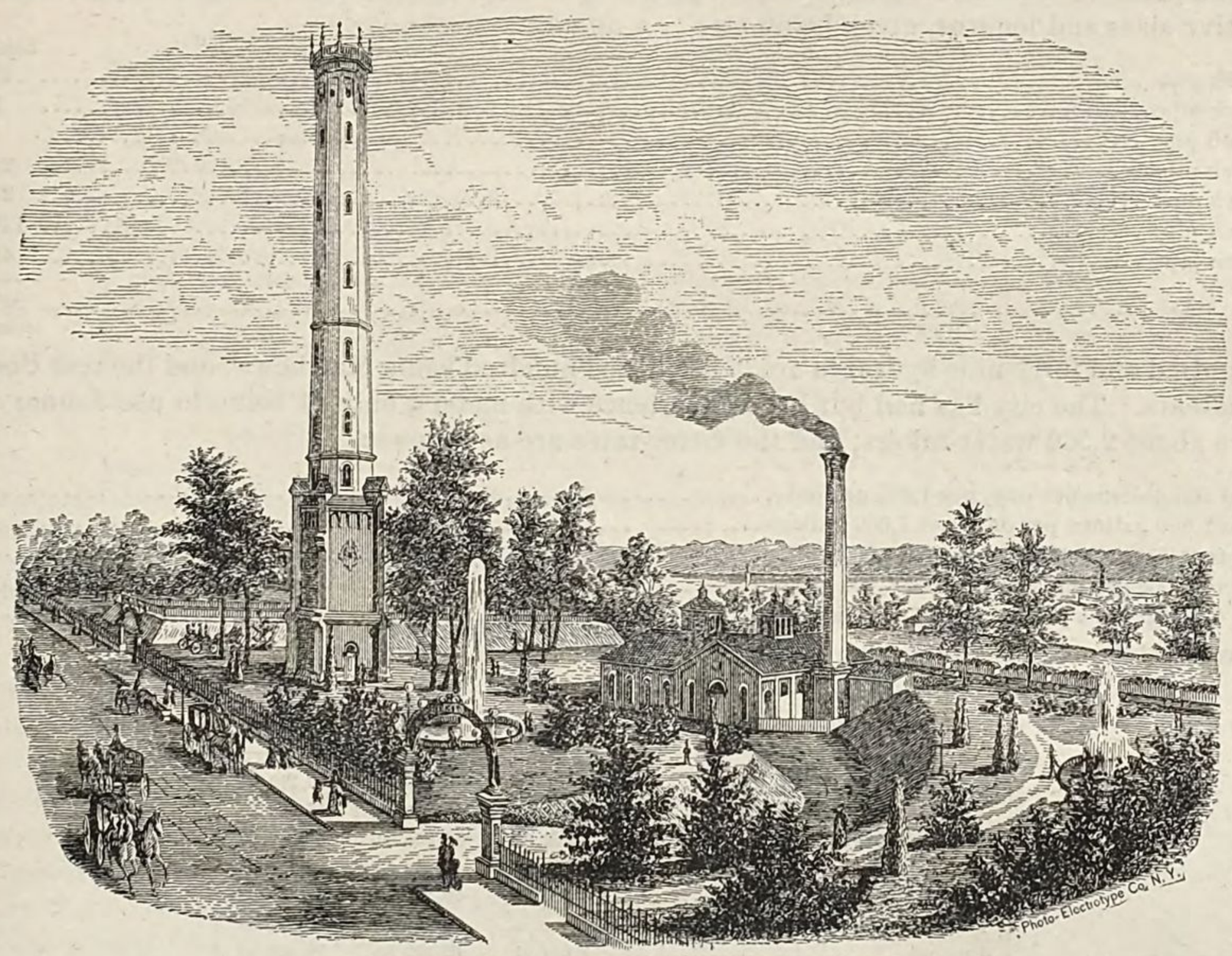
The municipal authorities introduced a supply of water from the Maumee river in 1873, the system employed being direct pumping to stand-pipe. The suction-main is taken from a crib in the river, of the following construction: It is a rectilinear figure, six-sided, with its longer sides parallel with the river, and 80 feet long, the other sides being 37 feet each. It is composed of lines of piling 5 feet apart and 45 feet deep, bound together by 10x12-inch timber; broken sandstone fills the space between the rows of piling, covered with double planking. It required 415 piles, 28,000 feet of timber, 7,600 pounds of iron, and 1,709 cubic yards of broken stone. The river water passing through 5 feet of broken stone enters the wrought-iron influent-pipe from the crib to the influent gate-chamber. At this point a brick conduit enters the pump-well of the engine-house. By an arrangement of valves and a middle main connected with the two rising mains, either engine is made to supply water from the pump-well to a filtering basin, while the other one pumps from the latter into a stand-pipe, there being two engines in use.



INTERIOR OF FILTER-BASIN, STAND-PIPE IN THE DISTANCE.

The suction-main is composed of 250 feet of boiler-iron 5 feet in diameter, connected by 250 feet of brick conduit of the same diameter to the pump-well. The filtering basin, which has been recently abandoned, is one of three originally projected. It is rectangular in plan and 150 by 300 feet, lined with masonry, with vertical interior walls, and a division-wall at one end, partitioning off the clear-water well. The bottom of the latter is connected through the division-wall with the large compartment. The filtering material consisted of a bottom layer of 4-inch stones, 1 foot in depth, with another layer of smaller stones 8 inches in depth above it; the last two layers are gravel and sand each 2 feet thick, making the whole depth of filtering material 5 feet. The water

pumped from the river into the basin by one of the engines flows back from the clear well to the remaining engine under a head of 12 feet, from whence it is pumped into the stand-pipe. On the 12th of January, 1875, water was let on to the filter-bed. The filtering area is 18,200 square feet, and, when first used, its actual capacity proved to be 4,500,000 gallons per day, while the best results were obtained when filtering but 2,500,000; at that time the river water was particularly clear. A few months later high water, bringing with it great quantities of clay in suspension, rendered the filtration imperfect and unsatisfactory to such an extent as to render the surface of the sand almost impervious. As a consequence, cleaning was necessary as often as once a week, and as there was but one basin, during the operation water was drawn from the river direct. Financial embarrassment prevented the construction of a needed duplicate basin. The advantages gained from the filtration seem to have been doubtful, if the appended analyses of water before and after filtration can be trusted. The basin was abandoned after a few



PUMP-STATION OF TOLEDO WATER-WORKS.

months. The stand-pipe is a wrought-iron pipe 5 feet in diameter and 243 feet to its top, which is 260 feet above the level of the river, and is inclosed in a brick tower, as shown in the cut. This stand-pipe is connected with the pumps by two mains, each 24 inches in diameter and 80 feet long. There are one 30-inch inlet and three 30-inch outlets; only one of the latter is in use. The tower of masonry is stone, 7 feet thick under the base of the pipe, and 36 feet square at its base, 16 feet below ground. Three feet above the ground, its inner diameter is 16 feet, with the same outer dimensions as before. It contains 682 cubic yards of stone masonry and 1,242,000 brick. It was originally the intention to construct a spiral stairway around the pipe, but a hydraulic lift is to be substituted.

The pumping plant consists of two Worthington duplex pumps, with low-pressure cylinder 50 inches in diameter, high-pressure 29 inches in diameter, pump piston 20 inches in diameter, with a stroke of 4 feet. They run at an average speed of 33 strokes per minute. The ordinary duty averages 37,000,000 foot-pounds, while with good coal it has run up as high as 55,000,000. The condensers are 30 inches in diameter and 5 feet long. The air-pumps of one of the engines are 18 inches diameter, and of the other 16 inches, all having a 2-foot stroke. A poor quality of bituminous coal is used under eight boilers made by the Novelty Works of Toledo, each 16 feet long and 5 feet in diameter, multitubular pattern, with sixty-two 4-inch tubes in each. Average pressure, 50 pounds. Evaporation unknown. The performance of the engines for 1879 is given below:

Pounds of coal consumed	4,316,477
Pounds of coal for banking fires	29,300
	4,287,177
Gallons of water pumped	1,140,625,640
Hours of fire pressure	109
Height in feet	163
	579

Gallons of water 1 foot high with 100 pounds of coal	43,366
Duty, in pounds, of water raised 1 foot with 100 pounds of coal	36,169,244
Cost of coal	$4,849 58
Cost of engineer, firemen, and helpers	4,683 04
Cost of oil, waste, and tools	380 89
Engine repairs, gas, and packing	401 49
Total cost of pumping	10,315 00
Cost of raising 1,000,000 gallons 1 foot high, in cents	5.54

The ordinary head on the pumps is about 60 pounds, and 120 pounds during fires. Their cost was $89,148.

The consumption in 1879 averaged 3,133,586 gallons per day, distributed through $46\frac{4612}{5280}$ miles of cast-iron main, of relative sizes and lengths, given below:

	Linear feet.
30-inch pipe	15,847
24-inch pipe	3,444
16-inch pipe	198
12-inch pipe	20,180
8-inch pipe	34,056
6-inch pipe	132,157
4-inch pipe	41,610
Total	247,492

Three hundred and forty-nine hydrants are in use, three hundred being Matthews', and the rest Boston Machine Company's patents. The city has had but little experience with meters, only 41 being in use January 1, 1880.

There are about 2,500 water-takers, and the meter-rates are as follows:

	Cents.
100 to 500 gallons per day, per 1,000 gallons	20
500 to 1,000 gallons per day, per 1,000 gallons	17
1,000 to 2,000 gallons per day, per 1,000 gallons	12
2,000 to 4,000 gallons per day, per 1,000 gallons	10
Over 4,000 gallons per day, per 1,000 gallons	8

An abstract of the cost of the works, giving the different items, is annexed:

For what expended.	1872–'73.	1874.	Total.
Pipe and specials	$176,607 96	$279,611 06	$456,219 02
Pipe-laying	17,711 29	100,214 10	117,925 39
Fire-hydrants	5,262 66	16,804 90	22,067 56
Gates and valves	4,522 88	19,630 62	24,153 50
Filter-beds and crib	308 14	29,246 89	29,555 03
Engine- and boiler-house and stack	.....	26,432 58	26,432 58
Engines	7,084 01	69,322 89	76,406 90
Stand-pipe	9,865 33	22,960 05	32,825 38
Pumping-wells	.....	1,600 77	1,600 77
Brick conduit	.....	3,996 96	3,996 96
Influent-pipe	.....	4,696 15	4,696 15
Sewerage	363 64	1,425 54	1,789 18
Engineering, etc	4,337 79	8,770 40	13,108 19
Salaries	9,388 25	11,345 24	20,733 49
Legal services	200 00	50 00	250 00
Traveling and telegraphing	1,421 37	265 39	1,686 76
Printing, books, and stationery	1,084 83	1,088 53	2,173 36
Office expenses	1,554 80	682 59	2,237 37
Implements, etc	429 49	785 82	1,215 31
Land	31,377 54	.....	31,377 54
Telegraph to works	.....	220 00	220 00
Coal-house	.....	739 24	739 24
Pipe-yard	156 62	23 36	179 98
Interest	44 67	319 05	363 72
Temporary works	308 29	11,946 77	12,255 06
Main works	.....	561 30	561 30
Ferrules and plumbing	.....	1,772 79	1,772 79
Water-meters	.....	6 94	6 94
Total	272,029 56	614,519 93	886,549 49

This sum has been increased in subsequent years as follows: Construction, exclusive of tools, to December 31, 1876, $930,726 40; in 1877, $1,699 58; in 1878, $28 12; in 1879, $658 48; sand account to December 31, 1876, $31,377 54, making a grand total of $964,490 12 to January, 1880.

The annual cost of maintenance and repairs for 1879 amounted to about $17,000, not including interest.

The analyses of Toledo water previously mentioned are given herewith as made in 1874 by Professor Silas H. Douglas, of Michigan university:

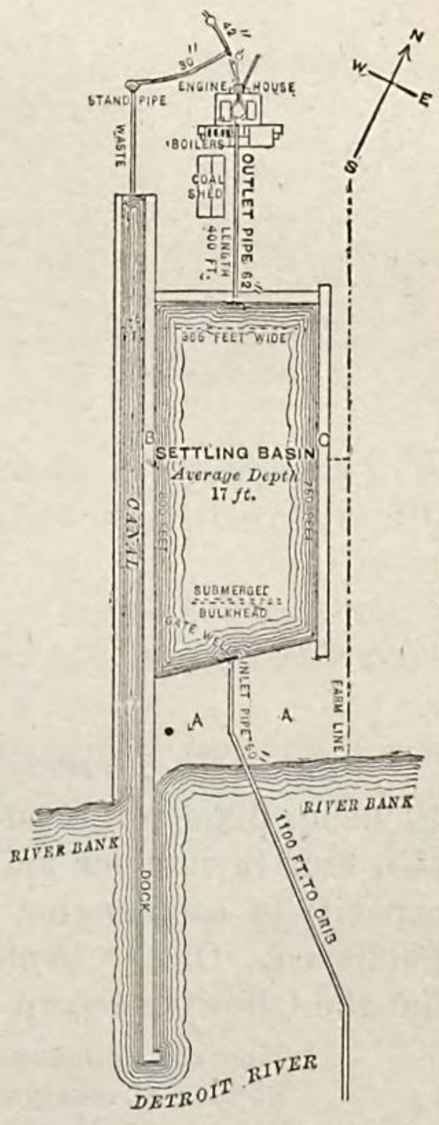
Constituents.	FILTERED.		UNFILTERED.	
	Grains per United States gallon.	Parts in 1,000,000.	Grains per United States gallon.	Parts in 1,000,000.
Oxygen absorbed by organic matter from permanganate of potassium	0.0963	1.6	0.1176	2.0
Total solid contents	16.32659	283.2413	17.44079	299.3638
Consisting of { Volatile and combustible matter	1.16378	19.9503	1.20525	20.6458
Consisting of { Fixed salts	15.35281	263.291	16.23554	278.718
Earthy carbonates	9.65747	165.310	10.54020	180.637
Fixed salts, consisting of—				
Chlorine	0.84110	14.49	0.84110	14.40
Sulphuric acid	2.14020	36.395	2.14020	36.395
Nitric acid	Trace.	Trace.	Trace.	Trace.
Carbonic acid	4.67938	80.09	5.03029	86.24
Soluble silica	Trace.	Trace.	Trace.	Trace.
Lime	3.99036	68.32	4.73531	81.20
Magnesia	2.44118	41.801	2.22805	38.198
Potassa and soda	1.26059	22.285	1.26059	22.285
Oxide of iron	Trace.	Trace.	Trace.	Trace.
Total solids	15.35281	263.291	16.23554	278.718

Filtered.—Sediment slight, but containing, as shown under the microscope, abundance of infusoria. Hardness on Clark's scale from 1° to 16° (16° being the hardest).

Unfiltered.—Sediment slightly increased from filtered, and showing under the microscope a great variety of infusorial animalculæ. Hardness on Clark's scale, 12°.

DETROIT, MICHIGAN.

Detroit introduced a supply of water in 1827 under the control of a private individual, who sold his rights to the city in 1836. A new site was selected and new works were erected. These contain two small engines of 10,000,000 gallons capacity, and an 18,000,000-gallon engine built by the Dry Docks Engine Company of Detroit in 1871. In 1877, owing to the fact that the supply of water, which was then pumped from the Detroit river opposite the heart of the city, was much contaminated by sewers, a new set of works was completed at a point 4 miles above.



In 1880 the city contained a population of 116,340. Situated on a river of like name 7 miles below lake Saint Clair, it extends from 3 to 4 miles along the river and 2½ miles back from its banks. Its streets are laid out at right angles to each other, with the exception of several which radiate from the Grand Circus.

Topographically it is comparatively flat, having a slight rise from the river of about 50 feet per mile. It is chiefly a commercial center with considerable manufacturing interests.

The water is taken from the river through a cast-iron pipe 60 inches in diameter and 1,100 feet long, the river end of which is supported on the river bottom in 22 feet of water on a crib of timber filled with stone. This pipe enters a settling basin 400 feet from the engine-house, as shown in the cut.

This basin is trapezoidal in plan, 800 by 750 feet long on the sides, 365 by 370 feet on the ends, with an average depth of 17 feet. It is 200 feet from the river-bank, and the river-end of it has a submerged bulkhead 75 feet from the bank. On the western side is a canal 45 feet wide, extending parallel with and beyond it, and from which it is separated by two rows of sheet-piling filled in between with 14 feet of puddled clay supported by piles driven 7 feet into blue clay. On the engine-house end there is another wall similarly constructed; natural clay soil extends from the back of this wall to the engine-house, a distance of 400 feet. The east wall is of the same character, but 11 feet thick, and the natural clay soil beyond. The inlet-pipe enters the basin 6 feet above its bottom, and is 15 feet lower at its river-end than at its discharge into the basin. From the opposite end another 60-inch pipe, 400 feet long, conveys the settled water from a point 6 feet above the bottom into the engine-house pump-well. From this joint it is drawn by two compound condensing beam-engines with double-acting pumps and forced into the stand-pipe, whence it is conveyed to the reservoir. Both engines were designed by John E. Edwards, esq.

The first engine was built by the Detroit Locomotive Works in 1876, and the other by the Riverside Iron Works in 1880. They are alike in most respects, a description of one sufficing for the other.

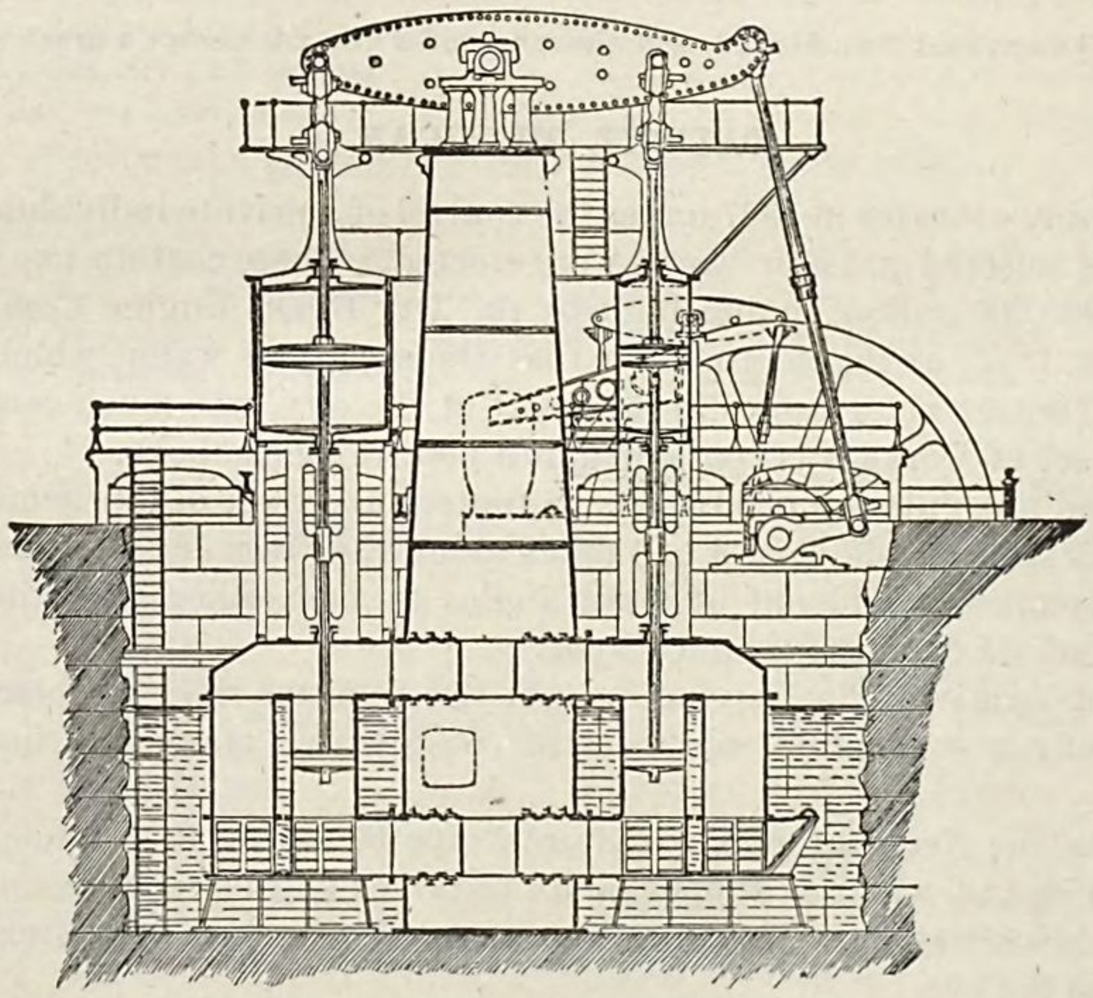
The old, or No. 1, has a low-pressure cylinder of 84 inches diameter, a high-pressure cylinder of 42 inches diameter, pump-cylinder 40¼ inches diameter; stroke, 6 feet; fly-wheel, 24 feet diameter; speed, 8 revolutions per minute; air-pump, 36 inches diameter and 30 inches stroke, operated by an auxiliary engine. The jet-condenser is 3 feet 9 inches diameter and 5 feet 9 inches high; vacuum, 26 inches. The steam-valves are puppet-valves operated by cams and plug-rods; cut-off at ⅓ stroke.

There are two pumps to each engine, of the plain piston type, each pump-cylinder having 116 discharge-valves of rubber 1 inch thick at each end, 9 inches diameter, and lifting from 1 to 1½ inch. There are also 48 suction valves at the end of the cylinders 19 by 7½ inches, rectangular, and lifting from 2 to 3 inches.

A battery of four marine boilers is used with each engine. They are of steel, 8 feet diameter by 17 feet long, with 4-inch return-flues, making steam at from 50 to 54 pounds pressure with anthracite coal. Evaporation unknown. The engine cost, with platform foundations and the like, $108,000, and gives a duty of 68,835,000 foot-pounds, and the following table will give its work during 11 months of 1879:

Time run, in hours	6,552.25
Number of revolutions made	3,008,431
Number of gallons pumped	4,693,152,900
Duty, in gallons of water raised (average)	69,000,000
Cords of wood consumed	20¼
Pounds of coal (*a*) consumed	5,033,742
Pounds of screening	632,364
Cost of wood	$57 05
Cost of coal	$9,216 51
Cost of screening	$454 18
Total cost of all fuel consumed	$9,727 74

The number of gallons pumped for 1 cent cost of fuel consumed for the year 1879 is 4,572.03.



COMPOUND PUMPING-ENGINE OF THE DETROIT WATER-WORKS.

Engine No. 2, erected in 1880, has a low-pressure cylinder of 84 inches diameter, a high-pressure cylinder of 46 inches diameter, a pump-cylinder 41 inches diameter; stroke, 6 feet. Other details as before. The boilers are also four in number and of the same description as the last. The cost of No. 2 was $83,000. The pumping capacity of each engine is 12,000,000 gallons. Details of the duty and operation of engine No. 2 are not yet published. Of the 18-million gallons engine in the old works, which was started in 1871, few details are at hand, but the following record will give its work in January, 1879:

Time run, in hours	744	Pounds of screening	90,001
Number of revolutions made	469,297	Cost of wood	$6 51
Number of gallons pumped	436,446,210	Cost of coal	$1,431 40
Duty, in gallons of water raised	43,135,700	Cost of screening	$53 86
Cords of wood consumed	2¼	Total cost of all fuel consumed	$1,491 77
Pounds of coal consumed	755,356		

a Anthracite, except 425,800 pounds bituminous used in January.

From the pumps a 42-inch main extends to the reservoir, a distance of 15,240 feet. An offset from this, a short distance from the pump-house, and 30 inches diameter, extends to a wrought-iron stand-pipe 132 feet high, the top being 128 feet above river-surface and 60 inches diameter at bottom. It tapers to 30 inches diameter at top, and is inclosed in a brick tower 17 feet 6 inches diameter at base by 12 feet at top. The walls are 3¼ feet thick at base and 21 inches at top. This tower rests on a stone base 16 feet high, with walls 4 feet thick at top and 5 feet at base. The waste from this stand-pipe empties into the head of the canal by the side of the settling basins. A new force-main, 42 inches in diameter and 23,000 feet long, is being laid.

There is but one reservoir, and this is situated 4,500 feet from the old pumping-works, at an elevation of 77 feet above the river at level of high-water surface in said reservoir; it is rectangular in plan, with a wall dividing it into two basins, each 200 feet square; the depth is 26 feet and capacity of the two basins 7,592,700 gallons; it is puddle-faced, with a riprapping of stone, slopes 1½ to 1 outside and inside, making the bottom 114½ feet square; width of banks at top, 15 feet. It was built in 1858.

The distribution system is composed of pipe varying from 30 inches to 3 inches diameter, amounting to 210 miles in 1880. This length consists of 86⅛ miles of wooden bored logs, some of which were laid as late as 1880, though in very small quantity, and the remainder are of cast iron.

There seems to have been considerable reason in the continued adoption of this system of log pipes. Their period of efficiency has proved to be about 16 to 20 years, and as their cost was only one-fourth that of iron pipe they were laid in the sparsely settled portions of the city. By the time that they were worn out the population on the street had grown sufficiently to defray the expense of a new cast-iron main. As a general rule, the former were paid for, principal and interest, by the time they had to be removed.

The iron pipe is divided about as follows:

	Linear feet.
45 inches diameter	50
42 inches diameter	16,244
30 inches diameter	4,313
24 inches diameter	34,564
20 inches diameter	406
16 inches diameter	1,510
12 inches diameter	2,050
10 inches diameter	49,302
8 inches diameter	63,586
6 inches diameter	175,985
4 inches diameter	243,170
3 inches diameter	34,238

Iron pipe laid in the year 1879:

	Linear feet.
10 inches diameter	1,839
8 inches diameter	4,773
6 inches diameter	20,439
4 inches diameter	15,980
3 inches diameter	7,802
Total feet	50,833

Equal to $9\frac{3313}{5280}$ miles.

Connected with these systems of wood and iron pipe there were, in 1880, 746 hydrants, of which 605 were Matthews' patent, the rest being plain wooden-box hydrants. In addition to these there are 5 other reservoirs, 167 large wooden tanks, and 141 smaller ones, making a total of 313 tanks.

There are about 1,200 Flower's patent stop-valves. The iron mains are laid 5 feet below the street-surface.

About 25,000 water-takers on the register consume an average of 16,000,000 gallons per day, at the meter-rates of 1 cent per 100 gallons.

The purity of the supply from the old works becoming questionable, owing to contamination by sewage and refuse from manufacturing establishments, the suction-pipe at the old works was extended into the river, and most of the water is pumped from the new works. The following analyses are of water from the river at various points, by A. B. Lyons, chemist, of Detroit:

Analyses of samples of water taken from Detroit river at various points.

[Parts to 1,000,000 parts of water.]

Where obtained.	Date.	Condition of water.	Free ammonia.	Albuminoid ammonia.	Chlorine.	Alkalinity estimated as carbonate of lime.	Condition of weather.
	1879.						
In river, American channel, at mouth of inlet-pipe	Aug. 25	Turbid	0.053	0.129	2.1	88	Strong S. W. wind. Weather dry. Temp. of air, 72° F. (nearly). Temp. of water, 71° F.
In basin, nearest pumping-works	Aug. 25	Somewhat turbid	0.055	0.125	.....		
In basin, near bulkhead	Aug. 25	Pretty clear	0.056	0.125	.....		
From hydrant, Stearns' drug store	Aug. 28	Slight sediment	0.045	0.120	2.1	88	
In basin, near pump-works	Sept. 1	do	0.042	0.110	.....	89	Air calm, smoky. Weather very dry. Temp. of air, 82 F°.
In basin, near inflow end of inlet-pipe	Sept. 1	do	0.043	0.110	.....	.....	
From hydrant at Stearn's drug store	Sept. 3	do	0.045	0.110	.....	.....	
In river, in middle Canadian channel, Belle Isle	Sept. 5	Moderate sediment	0.226	0.121	.....	86	Just after a heavy rain. Temp. of air, 67° F.
From hydrant, Stearns' drug store	Sept. 6	Slight sediment	0.205	0.125	.....	.....	
Do	Sept. 8	do	0.210	0.131	.....	.....	
In river, middle American channel, water-works	Sept. 16	Moderate sediment	0.065	0.142	.....	88	Weather showery. Wind westerly. Temp. of air, 72° F.
In river, middle Canadian channel, Belle Isle	Sept. 16	do	0.058	0.148	.....	.....	
Off Clark's dry dock, below city	Sept. 15	do	0.075	0.175	2.5	.....	
Foot of Twenty-second street, inshore, still water	Sept. 15	Clear	0.071	0.198	.....	.....	

Small as is the quantity of chlorine at present found in the river-water, it is considerably greater than it was a few years ago.

The following table shows the inorganic constituents of water of Detroit river, as taken from the hydrant, September 10, 1879:

Constituents.	Parts per 1,000,000.	Grains in wine-gallons.
Potassium sulphate	Trace.	Trace.
Sodium, chloride (salt)	3.93	0.229
Sodium, carbonate	5.75	0.394
Magnesium carbonate	20.73	1.209
Calcium carbonate	57.49	3.353
Calcium sulphate	17.89	1.043
Alumina	4.13	0.241
Ferrous carbonate (iron)	Trace.	Trace.
Silica	5.24	0.306
Total solids	115.16	6.775

These results compare favorably with those from Boston water.

The original cost of the works is difficult to ascertain, as they have been frequently changed and rebuilt. The total cost to the city amounts to $2,665,000 to October, 1880, and will amount to $2,915,000 to complete them as projected. Below is given an itemized statement of the cost of the new works up to January 1, 1878, and such as can be derived from sources of information at command up to 1880:

Items.	1874.	1875.	1876.	1877.	Total.	1879.
Land	$35,000 00	.....	.....	.....	$35,000 00	$601 00
Force-mains	.....	$138,211 37	$137,322 67	.....	275,534 04	32,350 14
Inlet-pipe	.....	16,469 05	5,675 40	$2,960 08	25,104 53	.....
Docks, basin, and canal	.....	63,706 50	40,344 63	1,168 92	105,220 05	66 67
Conduit and conduit-well	.....	.....	8,023 81	3,160 98	11,184 79	52 00
Engine-, boiler-, and coal-houses	.....	.....	58,464 28	41,351 87	99,816 15	391 34
Stand-pipe and tower	.....	.....	7,057 72	22,746 43	29,804 15	16 32
Pump-wells	.....	22,200 53	12,482 29	429 65	35,112 47	396 80
Engine	.....	55,935 51	43,850 46	2,341 51	102,127 48	44,385 45
Boilers	.....	.....	15,335 41	5,063 80	20,399 21	124 65
Engineer's house	.....	.....	.....	3,009 99	3,009 99	49 50
Sewer	.....	.....	3,587 69	33 24	3,620 93	386 65
Grounds	500 00	689 98	3,257 14	11,354 50	15,801 62	3,233 51
Inspection	.....	728 25	861 31	708 52	2,297 88	.....
Miscellaneous	1,781 88	1,052 91	229 87	528 53	3,593 19	759 06
Wood, pipe, and sundries	.....	.....	.....	.....	.....	1,905 00
Total	37,281 88	298,994 10	336,492 68	94,857 82	767,626 48	84,728 62
Grand total	.....	.....	.....	.....	.....	852,355 10

The expenditures on construction in 1878 amounted to perhaps $90,000, making a total to date of about $942,454, while the bonded indebtedness of the water board is $1,451,000 up to 1880.

The operating expenses for 1879 were $40,809. The receipts in the same time amounted to $106,045.

Meters are but little used as yet. The new works were designed by D. Farrand Henry, C. E., and the present works are under the control of Chauncy Hurlbut, president, and Henry Starkey, secretary, of the water board.

CHICAGO, ILLINOIS.

Chicago contains a population of 503,185, and is situated on the southwest shore of lake Michigan, at an elevation of only 12 feet above its level. The site of the city is so level that the greatest elevation at any point is but 23 feet.

Water was first introduced in 1840 by a private corporation, and was derived from the lake. In the present water-works the old means of taking water from the lake have been discarded, and a tunnel under the bed of the lake brings water to the pumping-station from a crib placed 2 miles out in the lake.

This tunnel was begun in 1864, and completed, under the direction of E. A. Chesbrough, C. E., in 1867. The pier and crib contain a vertical shaft provided with three gates at different depths. It is connected with the shore—at which is another shaft—by the tunnel, excavated 30 feet below the lake bottom, 5 feet wide by 5 feet 2 inches high, and lined with brick. The excavation was chiefly through clay, and the cost of it, when completed, was nearly $500,000. A second tunnel, of 7 feet diameter, and located 46 feet from the first, was completed in 1874. It runs parallel with the first, and is connected with it at the lake end by means of a cross-tunnel at the crib, and after entering the old or North Side pump-well it extends through the city 4 miles, passing under the Chicago river and entering the well of the West Side pumping-station, which is 44 by 10 feet, built of dressed stone.

The old pump-well is 21 feet deep, and, being sunk in quicksand, was built with a curb of brick 31½ feet in diameter and 2¾ feet wide at the bottom, resting in a shoe of iron 2½ feet deep, having a sharp edge below and sunk by its own weight after the removal of the material below. The bottom is of oak planking in two courses, each 3 inches thick and covered with 10-inch pine timbers with concrete between them. On this was laid a layer of 3-inch oak planking, and the whole is covered with 9 inches of concrete.

Above this were built the engines, of 18,000,000 gallons capacity. They have two cylinders 44 inches diameter each, with 96 inches stroke; pumps double-acting, and 28 inches diameter beneath the steam-cylinders. They are condensing coupled beam-engines, and pump into a stand-pipe of wrought iron 36 inches diameter and 138 feet high, inclosed in a tower 154 feet high, octagonal in form, and built of stone.

There are two other vertical beam-engines, designed by D. C. Cregier, and built in 1871. They are of 18,000,000 gallons capacity each.

At the West Side works there are two condensing compound beam-engines with high-pressure cylinders, 48 inches diameter by 72 inches stroke. Low-pressure, 70 inches diameter and stroke 120 inches.

The pumps, located beneath the low-pressure cylinders, are of the bucket-and-plunger pattern, the latter being 36 inches diameter with 120 inches stroke, and the chamber being 31 inches diameter. These engines deliver water into a wrought-iron stand-pipe 5 feet diameter by 167 feet high, inclosed in a stone tower 190 feet high. The engines were built in 1876.

In connection with the original water-works there were some small reservoirs built, which are now totally useless, and water is no longer forced into them.

The distribution consists of 450 miles of cast-iron pipe, none less than 6-inch being laid. The consumption amounts to about 57,500,000 gallons per day, but occasionally reaches 75,000,000 gallons. The capacity of the works is 100,000,000 gallons per day.

There are about 62,000 services in this system and 2,000 meters, the majority of which are of Worthington's make, with some "Gem" and "Ball & Fitts".

The total cost of the entire works up to 1880 was $8,645,000, and the revenue to the same date, $10,334,600.

The works are in charge of the city engineer, Mr. D. C. Cregier.

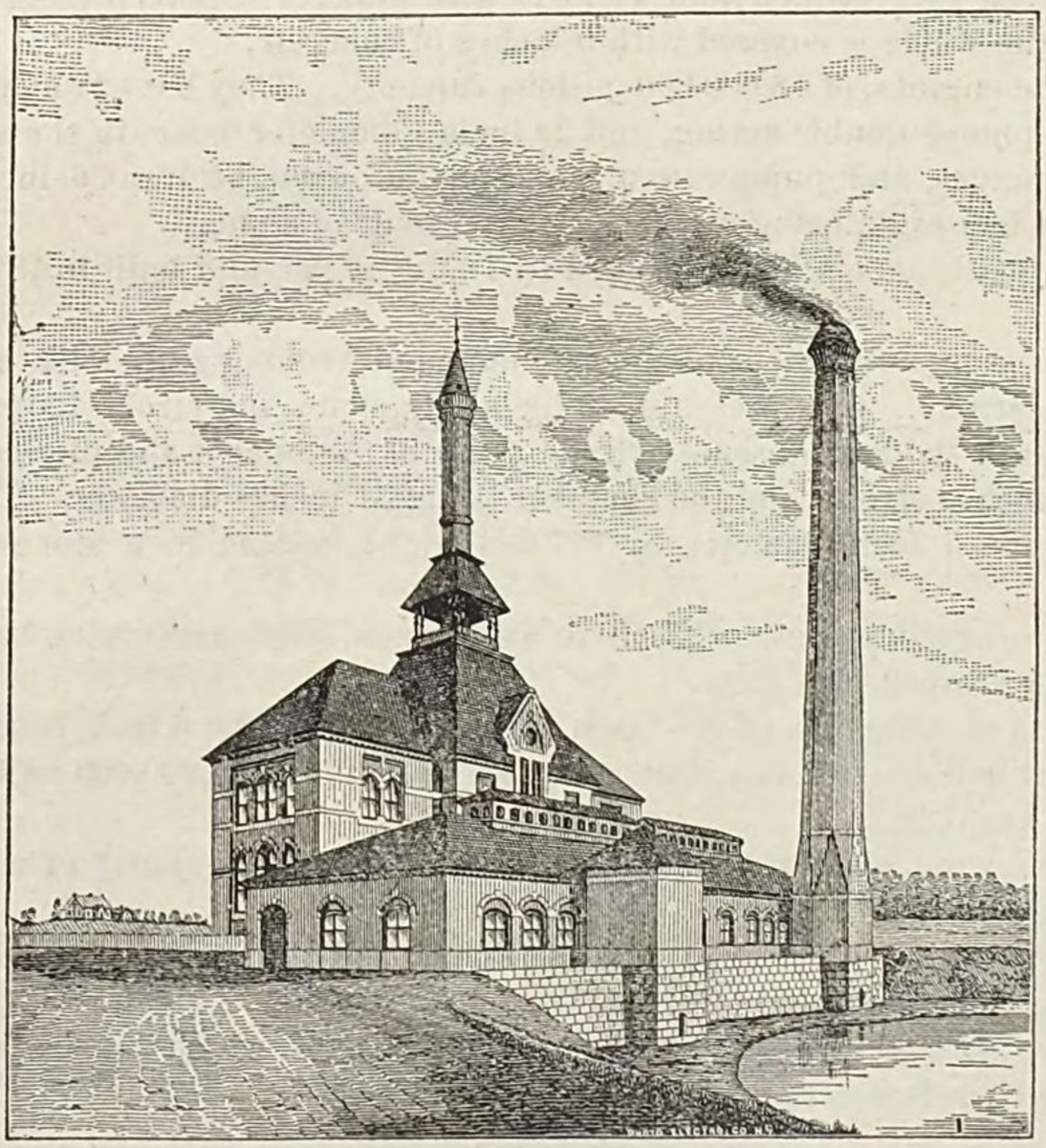
The Chicago works have formed the subject of elaborate reports, which can be found in almost any of the public libraries. They have therefore been but briefly treated here.

4.—PUMPING THROUGH STAND-PIPE—SURPLUS TO RESERVOIRS.

PROVIDENCE, RHODE ISLAND.

This city contains a population of 104,857, and is situated at the head of Narragansett bay, on Providence river. Its streets are laid out with great irregularity. Topographically it is also very irregular, some parts of it being elevated over 100 feet above the rest in the length of a few blocks.

The water-works were begun in 1870, under a resolution of the city council, and were completed in November, 1871. They have always been under municipal control. The system in use is pumping to a distributing reservoir, the water being derived from the Pawtuxet river, near the village of Pontiac, about 6 miles from the heart of the city. This point is known as the Pettaconsett pumping-station, and the main works are located there. The drainage area of the Pawtuxet river is a little over 192 square miles. At the pumping-station the Pawtuxet amounts to a considerable stream, from 15 to 20 feet deep, with a velocity of about 1 mile per hour. The width is perhaps 90 feet. The principal part of its bed is gravel and sand, the water being of fine quality.

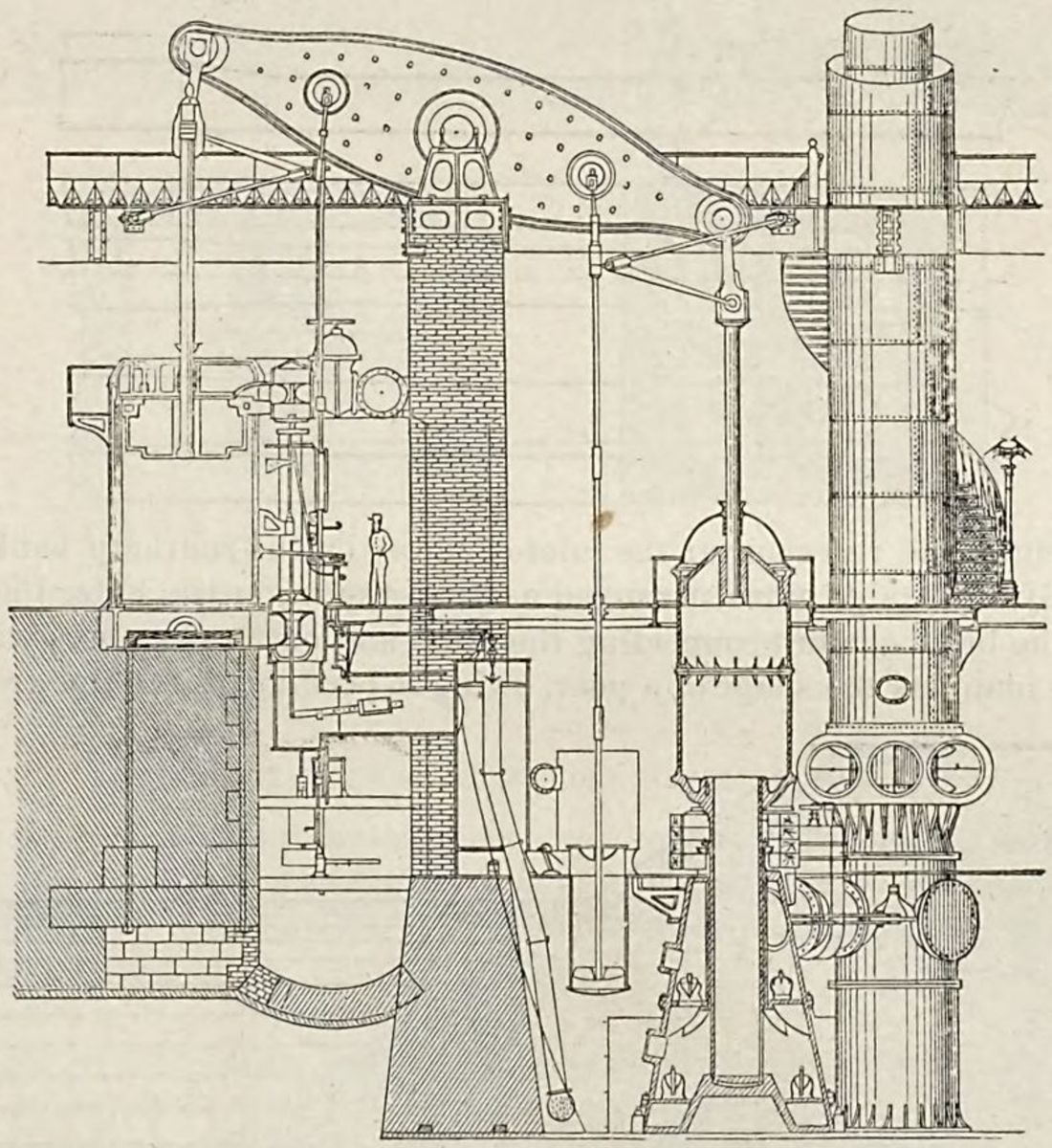


MAIN PUMPING-WORKS, PROVIDENCE, R. I.

At Pettaconsett station there are two distinct pumping-houses, one containing the permanent engines, and the other known as the "temporary works." The latter consist of a low wooden building on the bank of the river, containing a single Worthington engine, with two boilers attached. It was erected in 1871, and supplied all of the water used until the completion of the Cornish engine. The diameter of the pump-plungers in the Worthington duplex is 22 inches; stroke, 47 inches. It is a condensing compound engine, the diameter of the high-pressure cylinder being 20 inches, and of the low-pressure, 36 inches.

The capacity is 5,000,000 gallons per 24 hours. Actual duty, 56,000,000 foot-pounds, and it pumps about 21 hours per day at present. Its guaranteed duty was 50,575,000 foot-pounds. The two boilers used in connection with it are horizontal multitubular, 5 feet in diameter by 17 feet long, making steam under an ordinary pressure of 63 pounds. No experiments have been made to determine their evaporative power.

The permanent works are located a few hundred feet farther from the banks of the river, and consist of an engine-house of granite, iron, and brick, as shown in the accompanying view, 129 feet by 56 feet, with 44-foot wings; a boiler-house 179 by 55 feet, with a repair- or machine-shop of 123 by 70 feet dimensions. Height of engine-house 49 feet, and of boiler-house 13½ feet. Only one chimney has as yet been constructed, and, although there is space for four engines of the Cornish pattern, there is but one erected. The stand-pipe may be seen rising through the center of the roof to the height of 185 feet. It is of boiler-iron, resting on a cylindrical casting 7½ feet diameter, 9 feet high, and 2 inches thick. Upon this base rests the inlet casting, 7 feet diameter, 8 feet high, and from 2½ to 3 inches thick. In this are four inlets 42 inches diameter each (only one being used). Upon this is a reducer 7 feet diameter at base, 3 feet 9 inches high, by 5 feet 6 inches diameter at top. Upon this the casting rests, containing three outlets 36 inches diameter each (two being in use). It is 4 feet 9 inches high by 2½ to 4½ inches thick. To its top the outer shell of the stand-pipe, 8 feet diameter, is fastened. The inner shell, 5 feet 6 inches diameter, is secured to the flange of a circular opening in the bottom. The inner shell is 184 feet and the outer 189 feet high. The latter is ½ inch thick at bottom to a height of 54 feet, ⅜ inch thick for the next 56 feet, the remaining height being ¼ inch thick. A brass and composition check-valve, 12 inches diameter, is placed in the interior pipe.



PROVIDENCE WATER-WORKS—CORNISH PUMPING ENGINE NO. 1.

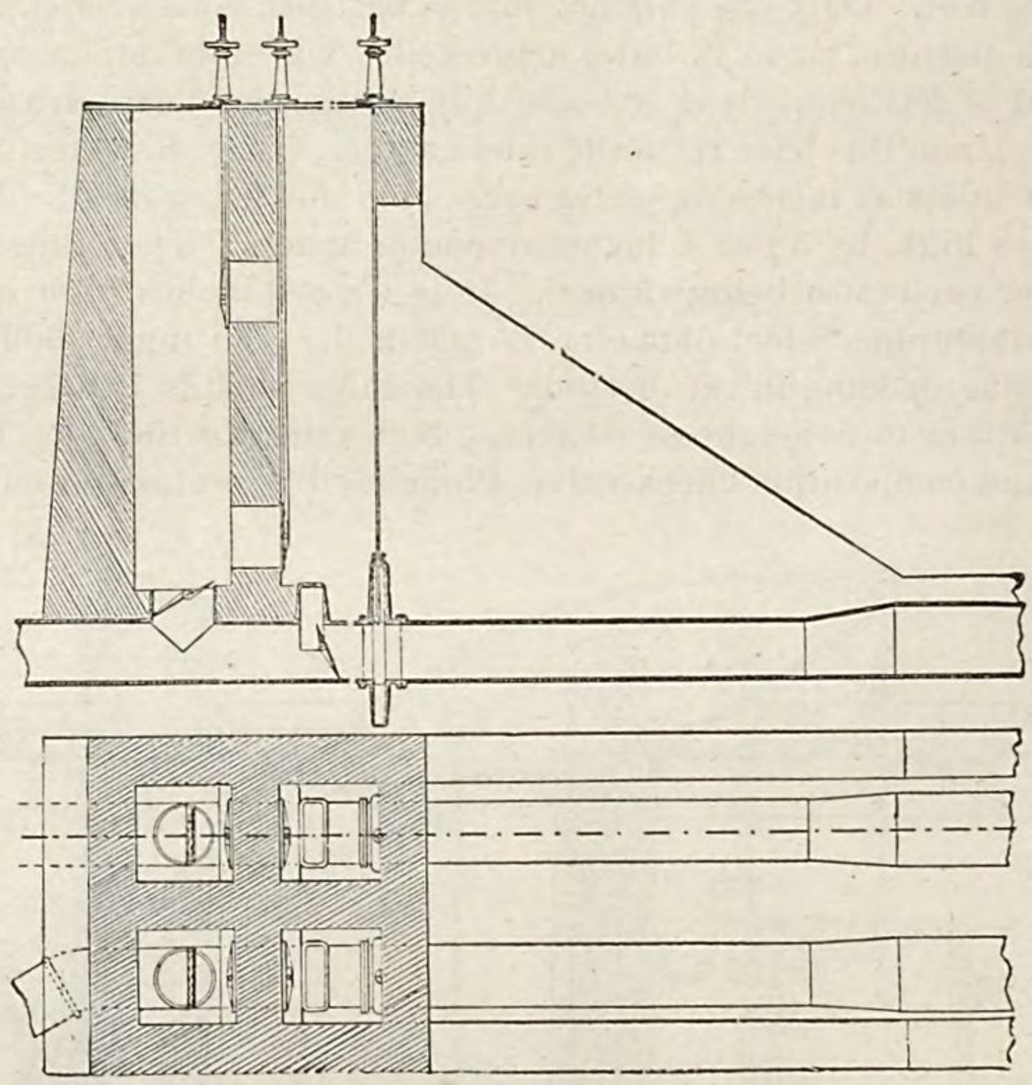
The Cornish engine, of a capacity of 9,000,000 gallons per 24 hours, was erected in 1876. The beam, weighing 60 tons, rotates on an axis supported by a masonry-wall dividing the left-hand wing of the building from the main part; total length, 35 feet. Connected to the end in the wing is the steam-cylinder, 100 inches in diameter by 11 feet 2 inches stroke. The steam acts upon the upper side of the piston, and driving it down raises a weight attached to the pump-plunger, and this in turn by its descent forces the water through the mains into the reservoir. The pump-plunger is plain, 39 inches in diameter by 11 feet 2 inches stroke, displaces 695 gallons per stroke, and is run at about 6 to 7 strokes per minute. The pump-barrel is truncated cone-shaped, with the suction and delivery valves arranged about the plunger in a circle, the latter above the former. There are 12 suction- and 9 delivery-valves. They are double-beat puppet, 16 inches in diameter, with a maximum lift of 1⅝ inch. The discharge-pipe empties into the foot of the stand-pipe through one of the four openings therein, the other three being closed until the remaining engines are placed.

The air-pump is 40 inches in diameter, with 5 feet 5 inches stroke, and the spray-condenser 4 feet 5 inches diameter by 11 feet 10½ inches long. The duty of this engine was guaranteed at 65,000,000 foot-pounds, but by actual trial a duty of 90,000,000 foot-pounds has been obtained.

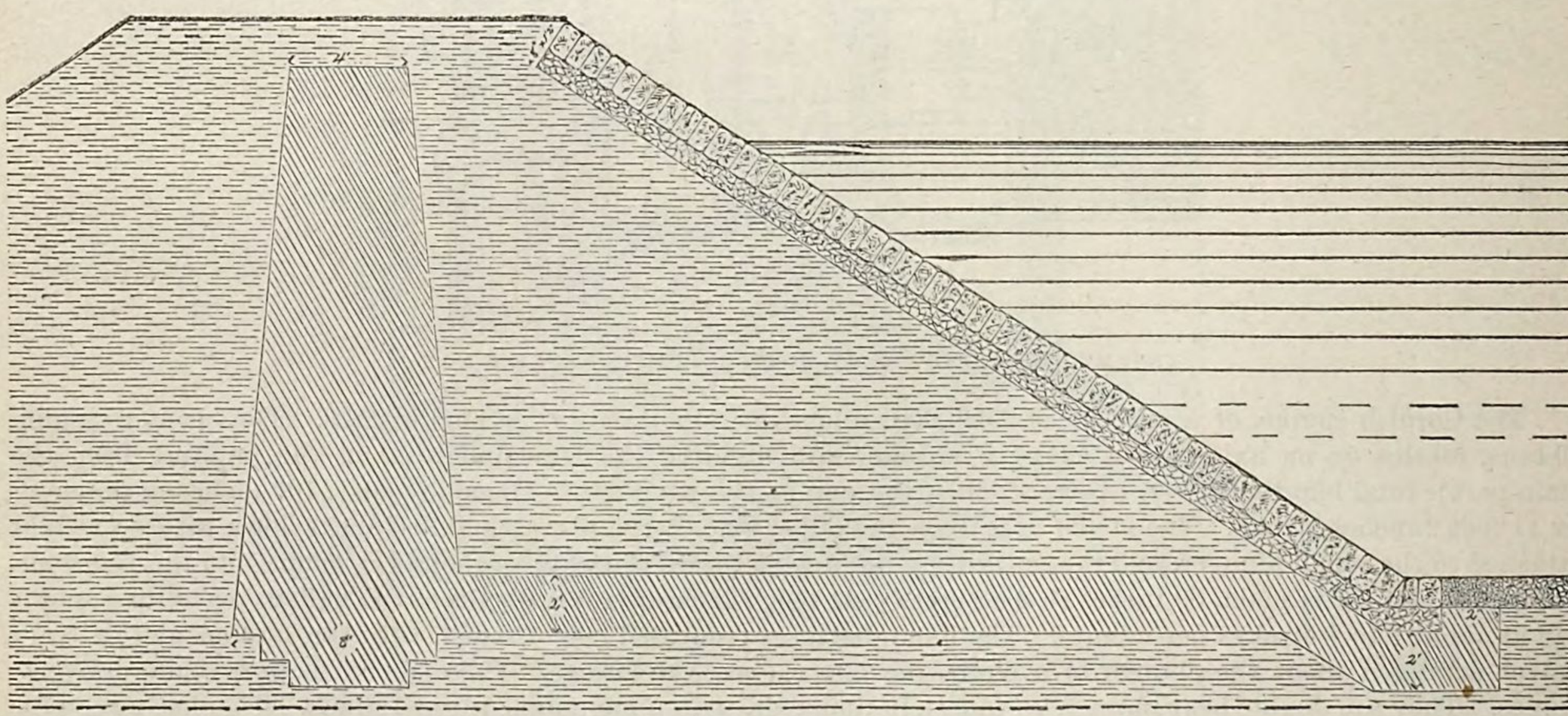
The boiler-house contains a battery of five Lancashire boilers, 7 feet in diameter by 28 feet long, each containing two flues, and run at a pressure of 40 pounds per square inch. Their average evaporative power is 8 pounds of water to 1 pound of anthracite coal.

There is room in the pumping-station for the erection of three more Cornish engines similar to the one already in position, and sixteen boilers—eleven besides those at present used.

From the engine-house two iron force-mains, 36 inches diameter, convey the water into Sockanosset reservoir, 1 mile north. The exact length of these two parallel mains is 10,084 feet, and the pressure at the pumps is due to



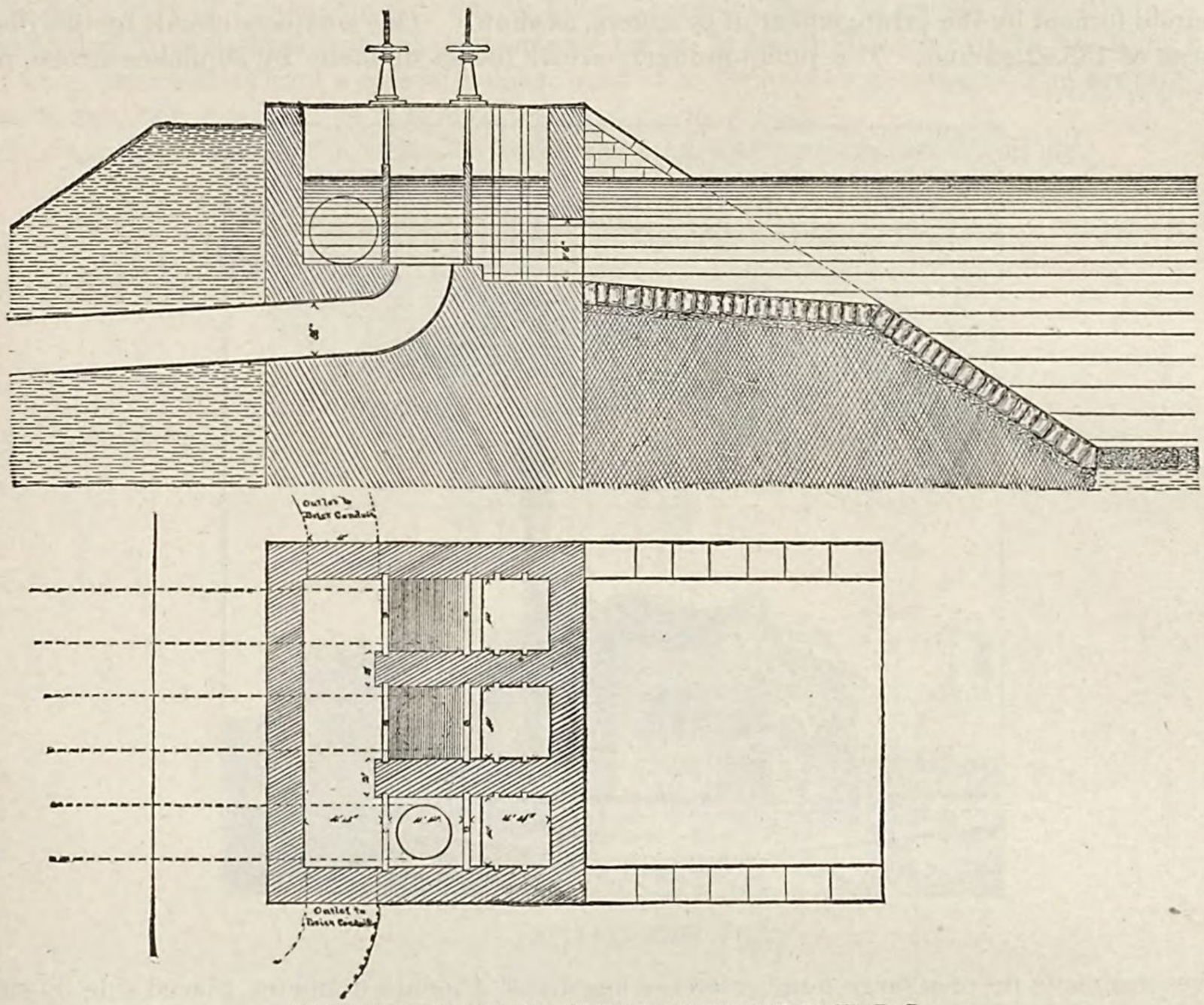
a head of 180 feet. They enter the reservoir at the inlet-chamber on the southern bank. This chamber is shown in the diagram annexed. By adjustable gates, arranged as seen, the water can enter the reservoir direct, or can be discharged backward into the brick conduit connecting the inlet- and outlet-chambers without passing through the reservoir. The reservoir in plan has the shape of a pear, owing to peculiarities in the ground. It is 1,000 feet long



RESERVOIR AT PROVIDENCE, R. I.

by 860 feet wide at the base, with a water-surface of 10.9467 acres when full and a bottom area of 9.5383 acres. Slope of banks, $1\frac{1}{2}$ to 1 inside and out; width of banks at top, 15 feet; depth from level of banks, 19 feet. The sides are entirely in embankment, with a puddle priming-wall 4 feet thick at top and 8 feet thick at bottom, as shown in the annexed diagram.

The outlet-chamber on the northern bank is connected with the inlet-chamber by a brick conduit 900 feet long and 4 feet in diameter, passing around the embankment outside of the puddle-wall, by which the water may be supplied directly to the mains without entering the reservoir. The inlet- and outlet-chambers have three compartments each, as shown. In the former the 36-inch force-mains from Pettaconsett, passing through the embankment, terminate in separate compartments, so that the water can be sent into the reservoir or direct into the 900-foot conduit above mentioned. From the similar compartments in the outlet-chamber the 30-inch pipe-mains



OUTLET-CHAMBER OF RESERVOIR, PROVIDENCE, R. I.

to the city pass through the banks. They are parallel, two in number, and of a total length of 59,076 feet. In the city, at Mathewson street, one diminishes to 24 inches diameter, crosses the river under Exchange Place bridge on iron piles, and terminates at Hope reservoir and the Hope engines. At Dorrance street the other 30-inch main diminishes to 24 inches, and crosses under Great bridge on iron piles; at Waterman street a 30-inch branch connects it with Hope reservoir.

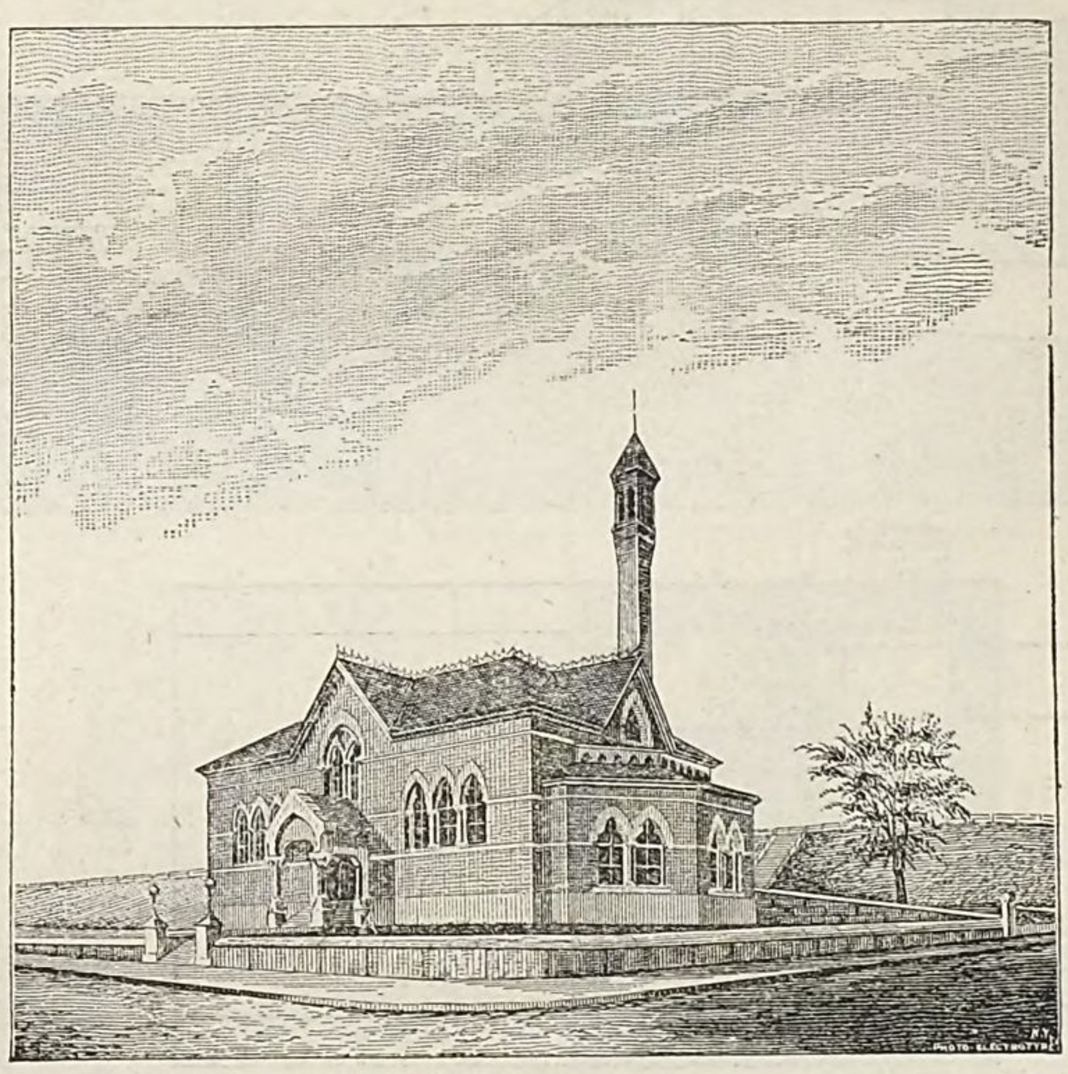
Hope reservoir, located in the city limits, on Olney street, is irregular in outline, 950 feet long, 840 feet wide, and 24½ feet deep. Area of reservoir bottom, 10.6 acres; area of high-water surface, 12.6 acres; area covered by embankments, 5 acres. Elevation at high water above mean high tide in Providence river, 162.5 feet; capacity, 76,000,000 gallons. The banks have a puddle-wall 4 feet thick at top and 8 feet at bottom, with section exactly similar to that of Sockanosset, as shown, and are 15 feet wide at the top. Slope, 1½ to 1 inside and out. The inner face of the banks is riprapped with granite blocks from 12 to 14 inches thick. The main from Sockanosset reservoir enters Hope reservoir at the bottom, near the center. The water leaves it through two chambers in the embankment, one at the northerly and one at the southerly side. These gate-chambers are provided with gates, by which water may be drawn from top or bottom.

An overflow waste-way is constructed at the northeast corner of the reservoir. The force-main, during the inactivity of the engine or diminution of pressure from it, acts, by means of the automatic valves, as a supply-main, the gate at top or bottom being opened.

Hope reservoir, as before stated, receives its supply by gravity from Sockanosset reservoir with an elevation of 18 feet above high-water mark in the former. From one of the mains entering Hope reservoir the high-service pumping-engines at "Hope Station" take their supply and force it direct into the distribution mains of the higher levels. The engine-house is of brick, with granite trimmings, as shown in the annexed illustration. The coal is stored in vaults at the rear. The engine-house is 73 by 50 feet, with a boiler-room in the rear 27 by 45 feet. It contains two high-service engines, automatically adjusting themselves to the pressure, varying at different times in the day. One, erected by George H. Corliss, in 1873, is of peculiar pattern. The other was designed by

Mr. A. F. Nagle, and built by the Providence Steam Engine Company, in 1876. It might be well here to say that, although not well constructed as to strength, the Nagle engine has shown a high duty and has done efficient service. The peculiar nature of the service required of these two engines renders it difficult to obtain a fair duty trial of either, as the head or pressure against which they pump is ever varying.

The Corliss engine, of 5,000,000 gallons daily capacity, consists of five individual pump-cylinders, arranged around a common center, with a steam-cylinder between each two, or ten cylinders in all. The connecting-rods from the pistons of both the steam- and pump-cylinders are fastened to a movable horizontal disk of steel, at the center of the circle formed by the arrangement of cylinders, as shown. One complete circuit by this disk represents a total discharge of 135.42 gallons. The pump-plungers are 12 inches diameter by 30 inches stroke, plain pistons.



HOPE STATION.

The water-valves are made up of a large number of leather disks, 4 inches diameter, placed side by side on a steel rod, making a sort of leather rod, 4 inches diameter and 16 inches long, fitting into a semi-cylindrical cavity or seat and closing itself by gravity after the passage of the water. The valve-chambers, two for inlet and two for discharge, are seen above and below the pump-cylinders. The steam-cylinders are 20 inches diameter by 30 inches stroke, condensing the steam in a circular-pipe condenser, 50 feet long and 12 inches diameter, extending almost completely around the central pit. This 12-inch pipe contains within it another of 3 inches diameter, carrying the cold water. The air-pump, with a diameter of 23 inches and a stroke of 8 inches, is located in a pit on the left of the engine.

This pump underwent in 1874 a severe duty trial, and was found to work favorably at a speed of a quarter of a revolution per minute, and was tested to a velocity of 27 per minute. It draws the water from the low-service mains, as mentioned, under a back pressure of about 40 feet, and the average height to which the engine pumps (calculated from the average pressure) amounts to about 80 feet. The duration of the test was 48½ hours.

Average height pumped	feet	88.2882
Average number of gallons raised per minute		1,424.7
Average number of gallons raised per hour		85,482
Total number of gallons raised during run		4,145,877
Number of gallons raised at same rate per 24 hours		2,051,568
Full capacity of pump first 24 hours	gallons	2,064,535
Percentage of lost action of pump		3.36
Number of gallons actually raised first 24 hours (deducting for lost action of pump)		1,982,636
Coal consumed per minute	pounds	4.02
Total coal consumed	do	11,700
Ashes dropped	do	1,028
Number of gallons raised per pound of coal (full contents of pump)		354.4
Actual number of gallons raised per pound of coal		342.49
Cost of coal per annum		$7,352
Length of stroke	inches	30
Revolutions per minute (average)		10.167

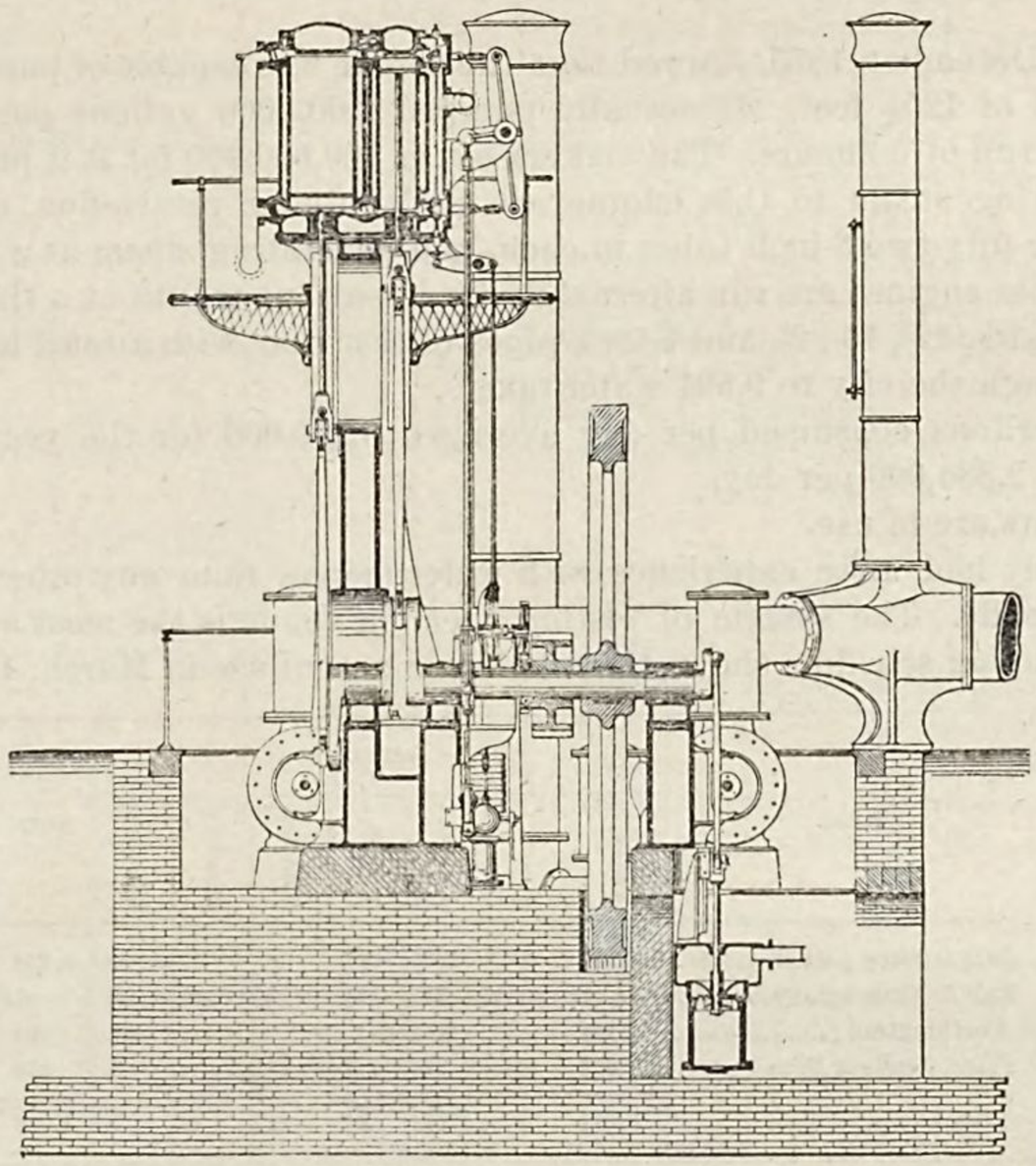
Temperature of water	degrees	41
Weight of one gallon at 41°	pounds	8.326
Duty, calculating resistances	foot-pounds	25,865,740
Duty, actual water delivered at 41°	do	25,176,384

During this duty trial there was, at the higher velocities, considerable noise from lost motion in connecting-rods, etc., and a visible expansion and contraction of the flat surface of the sides of the pump at each alternation of the pistons.

The actual daily duty of the engine is given by the engineers at about 15,400,000 foot-pounds.

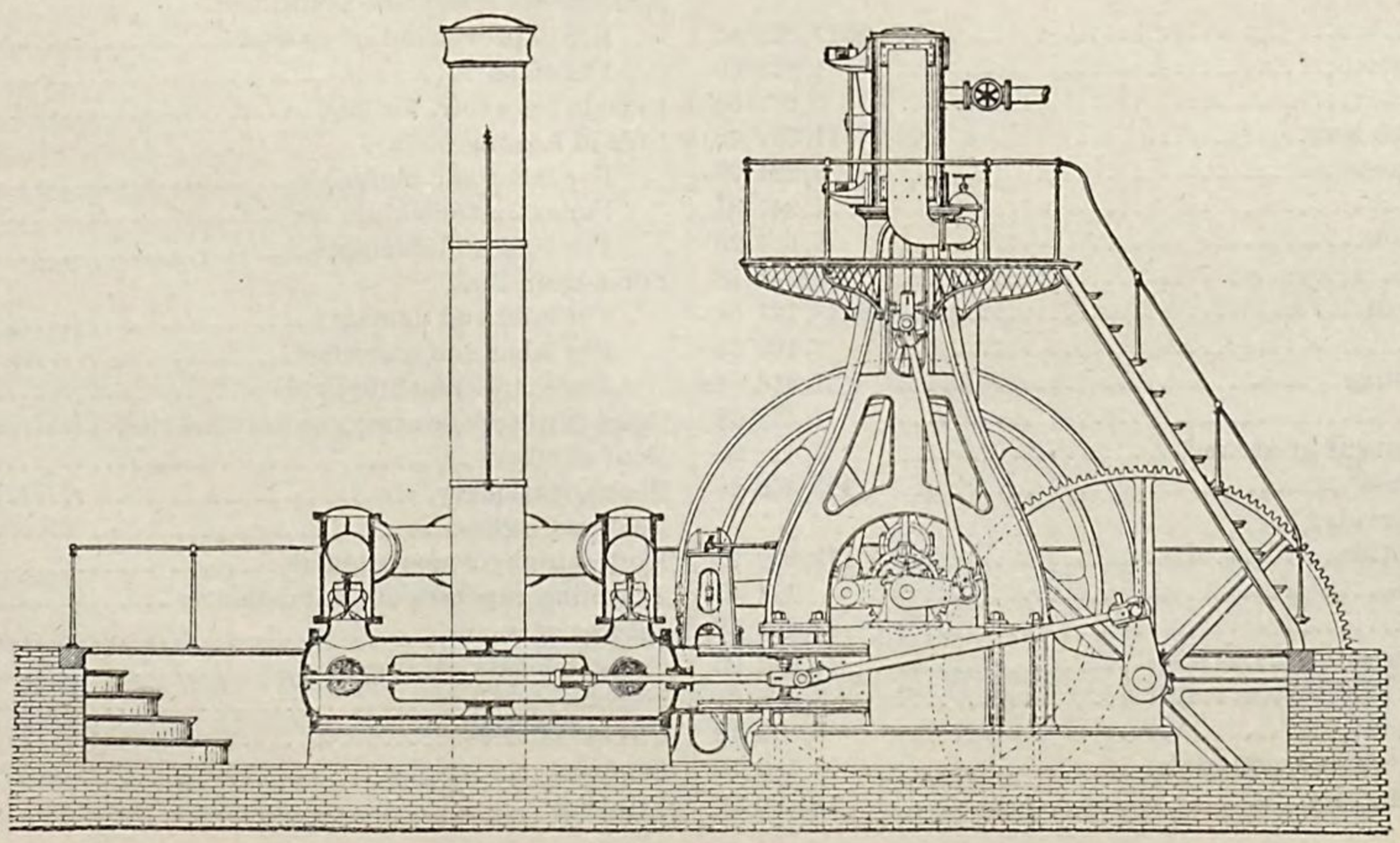
Steam is supplied from a single upright multitubular boiler, 7½ feet in diameter by 21 feet high, with 248 2-inch tubes, 10 feet long, arranged around a central hollow, used as a manhole or waterleg. The average pressure is 50 pounds; horse-power, 140; evaporation, 8 pounds water to 1 pound coal.

The Nagle engine, erected in 1876, is shown in the elevation and sections accompanying.



SECTIONAL ELEVATION THROUGH CENTER OF CYLINDERS.

It is a geared compound-condensing engine, with two horizontal double-acting pumps receiving their plunger motion as shown.



NAGLE ENGINE.

The diameter of the plungers is 17 inches; stroke, 8 inches; total capacity of engine, 5,000,000 gallons per day, with a displacement of 184½ gallons per revolution. Diameter of pump-barrel, 24 inches. This engine is also self-regulating to the pressure. The pump-valves, eight in number, four to each pump, two suction and two discharge, are brass double-beat puppet-valves, 1 foot 3 inches diameter. An air-chamber is connected with both the suction and discharge mains, as seen in the cut.

The engine has two cylinders, vertically placed—the high-pressure, 11 inches diameter by 42 inches stroke, and the low-pressure, 19 inches diameter with same stroke, the crank being opposite. The steam-valves are of the flat gridiron slide type, operated by sliding cams connected with the rocking levers seen in the cut at top. The condenser is a column-pipe, 22 feet by 10 inches diameter, with an interior pipe carrying the cold water. The exhaust-ports connect with the main or column pipe at a point 6½ feet above the top of the cold-water pipe within, and the fall of the water over the top of the cold-water pipe carries the steam with it to the foot, condensing it. The air-pump is 15 inches diameter by 18 inches stroke, of the drop-bucket variety, and can be seen in the sectional elevation.

The duty-trial made in December, 1875, showed that the engine was capable of pumping easily 5,106,805 gallons per 24 hours under a head of 125¼ feet. It actually pumped 2,000,000 gallons per 24 hours, giving a duty of 84,637,245 foot-pounds for a run of 56 hours. The makers claim 100,000,000 for it if pumping into a reservoir only.

The two boilers supplying steam to this engine are multitubular return-flue, of 12 feet length by 5½ feet diameter of shell, containing fifty-two 3-inch tubes in each, and generating steam at a pressure of 70 pounds.

The Nagle and the Corliss engines are run alternately for about one month at a time.

A system of 30-, 24-, 20-, 16-, 12-, 10-, 8-, and 6-inch pipes of cast iron, with a total length of 155.158 miles, serves to distribute the water through the city to 9,691 water-takers.

The total number of gallons consumed per day averaged 3,110,000 for the year 1879, the maximum being 3,782,000, and the minimum 2,384,000 per day.

About 1,137 fire-hydrants are in use.

Providence has probably had more experience with water-meters than any other city in the country, having tried almost every variety made. The system of testing them in vogue is the most accurate that came under my observation. The accompanying schedule shows the number in actual use in March, 1880:

Kind.	SIZES.							Total.
	⅝ inch.	¾ inch.	1 inch.	1¼ inch.	2 inches.	3 inches.	4 inches.	
Ball & Fitts, piston	2,584	493	125	47	8	1	.....	3,258
Ball & Fitts, rotary	.....	.....	13	14	2	5	3	37
Worthington	164	.....	.....	.....	.....	.....	1	165
Fales, Jenks & Sons	323	214	22	3	11	.....	3	576
Total	3,071	707	160	64	21	6	7	4,036

The annual cost of maintenance and repairs, exclusive of interest, is about $74,000. The total cost to date of January, 1880, was $5,442,179. The cost of construction is given in detail in the accompanying statement:

Hope reservoir:	
For land	$117,823 88
For sundries	1,813 60
For labor	6,828 65
For gate-chambers	11,567 48
For gate-houses	3,224 00
For drain	1,947 31
For inspection	8,614 26
For conduit	3,746 18
For slope-wall	43,127 81
For steps	3,103 33
For iron railing	1,418 81
For fence	1,482 18
For improvement of grounds	5,418 28
Hope engine-house	105,462 20
Sockanosset reservoir:	
For construction	177,870 72
For sundries	124 45
For land	14,305 36
For gate-houses	18,641 95
For drain	3,506 01
For inspection	6,819 18
For extra work and materials	189 70
For gate-chambers	19,299 27
Sockanosset reservoir—Continued.	
For improvement of grounds	$13,613 13
For steps	3,235 94
Lincoln reservoir, for land	2,946 54
Line of leading mains:	
For labor and materials	19,950 30
For extra trenching, etc	472 45
For land and damages	1,665 00
Force-main line:	
For land and damages	3,006 35
For labor and materials	6,505 29
For extra trenching, etc	332 56
Office furniture, stoves, gas-fixtures, etc	1,309 95
Rent of offices	2,875 00
Books, stationery, etc	667 59
Fuel and lights	225 10
Horse-hire by commissioners	19 00
Traveling expenses of commissioners	161 92
Janitor of rooms	484 51
Commissioners' salaries	22,042 18
Secretary's salary	2,855 52
Clerks' salaries	4,136 53
Sundries	502 49
Printing	2,275 40

Advertising	$1,935 38
Fences	2,075 38
Rent of wharves and pipe-yards	7,192 78
Stop-valves	74,504 18
Linking curved pipes	232 75
Store-house and work-shop	1,209 64
Tools	11,321 84
Labor on pipes	15,965 80
Cast-iron water-pipes	1,332,967 10
Special castings	103,538 79
Lumber	1,576 30
Fire-hydrants	107,540 46
Sockanosset Hill cross-road	3,855 38
Telegraph lines	2,262 17
Dwelling-houses at Pettaconsett	10,080 63
Culverts and bridge on line of force-mains	6,775 33
Culverts at Pettaconsett	3,557 92
Real estate in Warwick	11,383 86
Water privileges, mill, and other real estate in Pawtuxet	45,557 65
Pettaconsett pumping-station, for land	25,902 41
Pochasset bridge	5,559 82
Wharf salaries	11,624 46
Temporary engine-house at Pettaconsett	9,824 87
Roads, slopes, etc., at Pettaconsett	12,055 30
Engine-house at Pettaconsett	310,570 51
Natural filter-basin	41,518 35
Removing loam	462 95
Iron screw-piles	3,766 46
Hydrant-bolts	1,940 78
Pipe-bolts	1,933 70
Photographs	328 25
Hydrant-heads	7,511 51
Taps and stops	19,239 83
Valve-covers	9,370 72
Service-pipe	50,682 43
Hydrant-boxes	30,191 67
Setting fire-hydrants	10,774 48
Check-valves	3,712 48
Valve-boxes	34,550 42
Air-cocks, boxes, covers, and setting	527 02
Setting blow-offs	331 49
Lobdell & Newmans	188,025 00
A. & W. Sprague Manufacturing Company	2,500 00
Samuel M. Gray	300 00
Paulding, Kemble & Co	109,265 54
Thomas Phillips & Co	4,283 84
James Glass	4,495 26
Providence Steam-Engine Company	47,062 91
Rhode Island Locomotive Works	30,145 71
Architectural Iron Works	30,520 35
French, Mackenzie & Co	3,150 00
Wenscott Reservoir Company	44 45
Akron Sewer-pipe Association	5 25
Sewer department, salaries and office expenses	709 68
City treasurer	282,012 39
City treasurer, for water payments	545,374 12
Testing pipe iron	443 50
Iron drain-pipes and gate	224 21
Carting pipes	$40,301 87
Counsel fees	5,500 00
Inspection of pipes	10,312 23
Testing bolts and composition castings	34 25
Laying water-pipes	406,226 18
Laying service-pipes	32,549 24
Laying suction-pipe, etc	85 00
Drainage pump and engine	5,110 72
Hydrants for street-sprinklers, etc	2,639 50
Inspection of pipe-laying	33,968 14
Temporary boarding-house at Pettaconsett	1,433 23
Public drinking fountains and troughs	3,701 29
Warwick test-pits	1,313 40
Engine-house at Pettaconsett, for drain	2,132 37
Water-meters set, belonging to the city	1,258 72
Worthington pumping-engine	35,522 33
Hope pumping-engine	63,104 67
Cornish pumping-engine	11,545 47
Keeper's house at Sockanosset reservoir	7,088 84
Pipe in river embankment at Pettaconsett	4,067 82
Inspection of engine-work	5,287 08
Alterations at Hope pumping-station for second engine	784 59
Testing second engine at Hope pumping-station	4,779 62
Drain-tiles	489 79
Boilers for Cornish engine	9,449 08
Stand-pipe at Pettaconset	956 89
	4,919,738 13
Engineering department:	
For instruments	3,452 34
Tools	736 87
Furniture, stoves, gas-fixtures, etc	2,893 92
Draughting	3,523 52
Labor	9,945 58
Horse and wagon account	2,814 65
Horse-keeping, shoeing, etc	2,848 94
Horse-hire	5,499 65
Rent of offices	7,081 87
Fuel and lights	749 83
Janitor of rooms	1,308 76
Experimental filter	91 08
Books, stationery, etc	3,619 04
Sundries	3,802 39
Test-wells	1,579 40
Consultations	827 08
Office building at Pettaconsett	567 60
Office building at Sockanosset reservoir	563 22
Stakes and strips	1,318 24
Printing	671 48
Maps	179 17
Service-pipe experiments	296 04
Temporary assistance	11,168 88
Salaries	98,904 50
	164,144 05
Total	5,084,182 18

The annual rainfall at Sockanosset reservoir varies from 45 to 50 inches.

The analysis of Pawtuxet water gives the following results:

	Grains per gallon.
Mineral matter	1.24
Organic matter	1.33
Total solids	2.57

This compares favorably with that of the principal cities in the East.

The water-works are under the general superintendence of Samuel M. Gray, C. E., city engineer, and the direct supervision of his assistant engineer, Mr. E. B. Weston.

5.—PUMPING THROUGH STAND-PIPE TO RESERVOIRS.

NASHVILLE, TENNESSEE.

This city, on the Cumberland river, and on irregular ground, contains a population of 43,350 inhabitants, and is chiefly a commercial city. The manufacturing interests are small. The streets are laid out at right angles to each other. From the river the banks rise sharply to a considerable elevation.

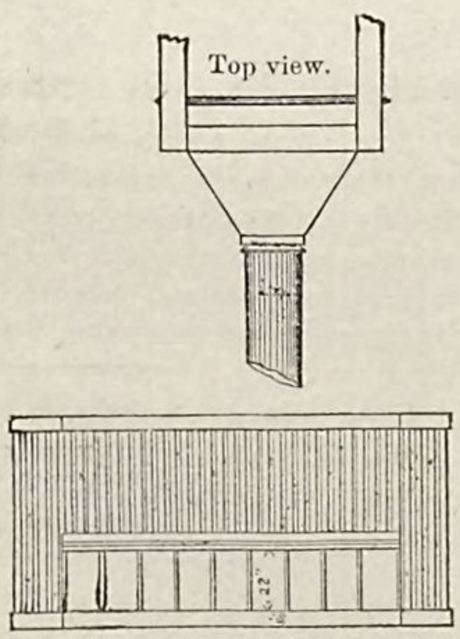
In 1832 a supply of water was introduced from the river by pumping through a stand-pipe into a small distributing reservoir on one of the highest hills in the vicinity, and now included in the city, the works being under municipal control.

The pumping-station is located on the southern river-bank, within the city limits, and derives its supply through 12,000 feet of pipe, 36 inches diameter, from an infiltration gallery located farther up the river, on a low island in the middle.

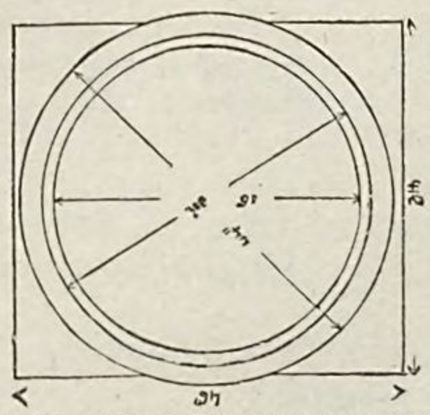
The construction of this gallery is unique. It is 152 feet long, 6 feet high, and 10 feet wide, filled with stones, and is, technically speaking, an infiltration gallery. The island on which it is built is a low-lying strip of sand a few rods in width and 100 acres in extent, and the river-water percolates through its banks into the gallery.

The latter is thus constructed: A couple of 18-inch iron channel-beams are placed vertically one over the other, and united by vertical iron rods placed 2 inches apart and fastened to the flanges of the beams. To prevent longitudinal motion the upper and lower beams are braced with inclined struts, like a truss-bridge. The depth between the upper and lower beams or chords is 6 feet. Another similar construction is placed longitudinally parallel with it in the same trench and 10 feet away. Across the top of the two thus placed, iron rails are put close together, forming a roof to the gallery, the whole of the interior being filled with stones. To prevent the side trusses from being forced together, iron tubes 10 feet long and 2 inches in diameter are placed against the inner flanges of the upper chords and held in place by 13½-foot bolts passing through both flanges of each chord and through the tubes, being fastened at the ends by nuts.

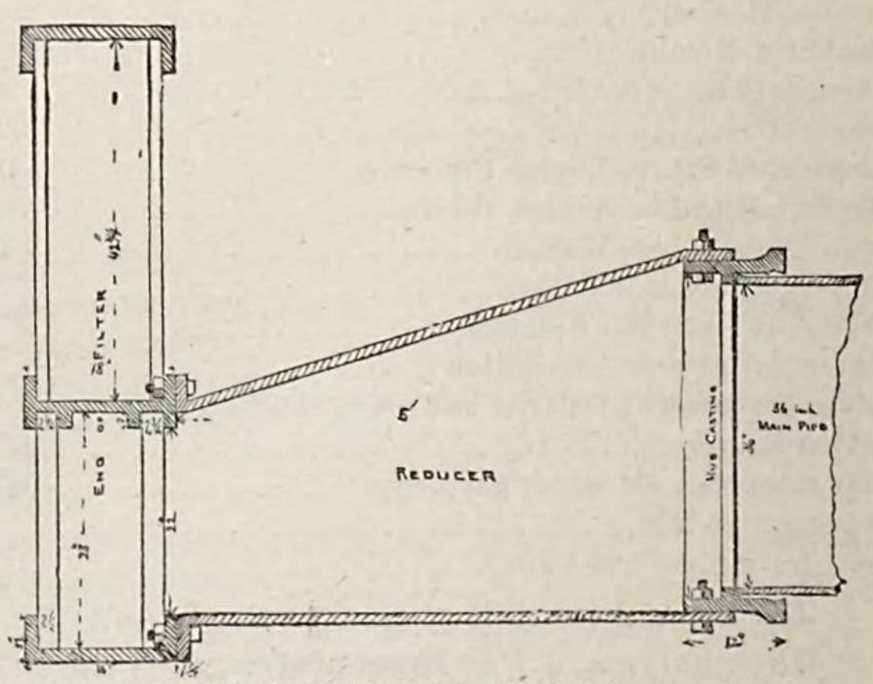
The lower chords are likewise kept apart. The whole construction is 25 feet below the surface of the island. From the lower end of the gallery thus constructed a cast-iron pipe 36 inches diameter is taken as shown in drawing, which extends to the pump-well of the engine-house, 12,000 feet, resting on the river bottom for its whole length.



END VIEW, SHOWING OPENING FOR REDUCER.



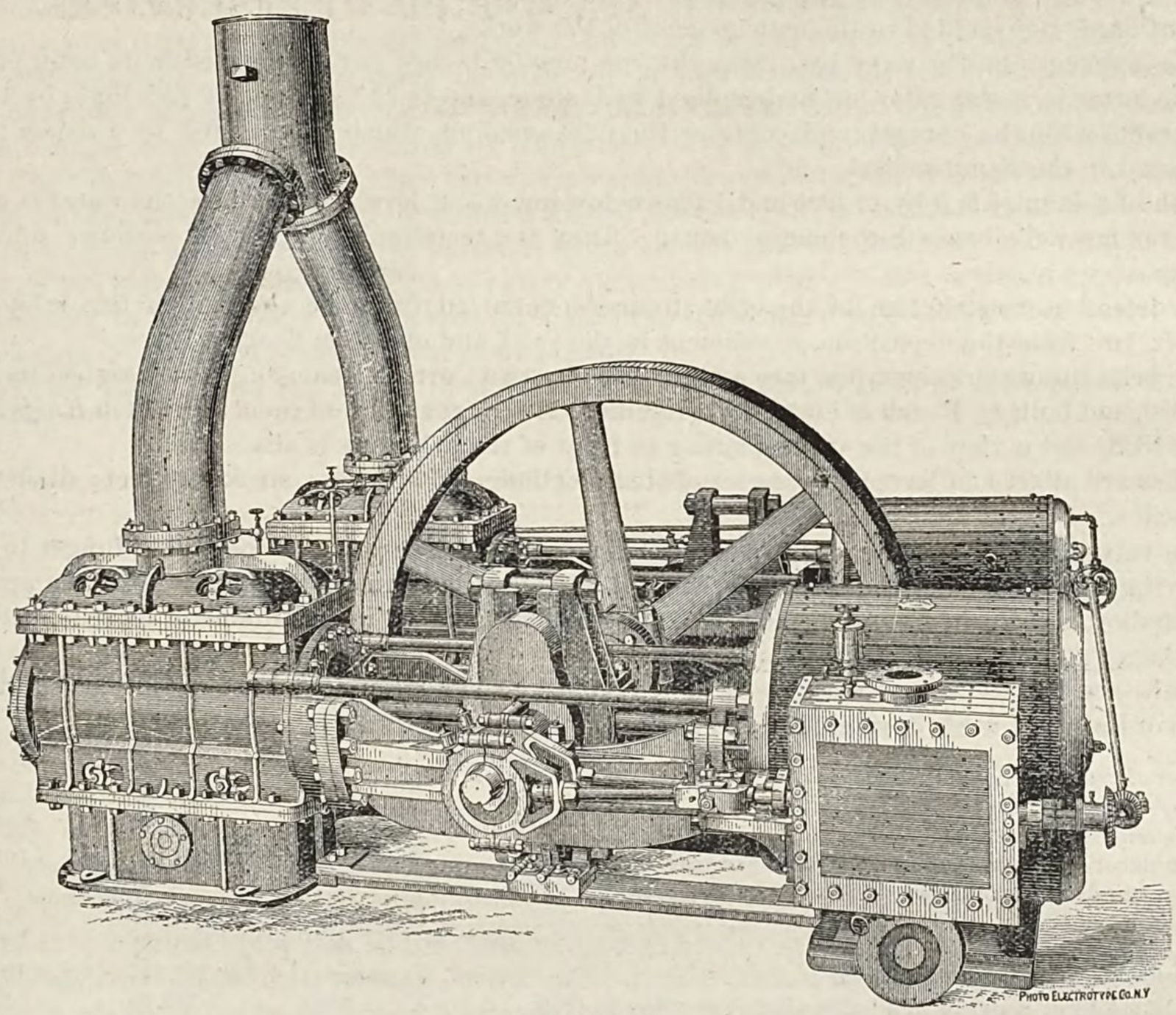
FRONT VIEW OF HUB CASTING.



LONGITUDINAL SECTION THROUGH REDUCER.

The engines are three in number—two of 5,000,000 gallons, Dean duplex, erected in 1877, and one 4,000,000 gallon engine by Nashville Manufacturing Company, in 1854, which is nearly useless. This latter, which is similar to the horizontal engines in the pit of the low-service engine-house at Cincinnati, is a high-pressure single-cylinder engine with steam-cylinder 24 inches in diameter, two pump-cylinders each 13 inches in diameter—stroke of former, 8 feet, of latter, 6 feet; fly-wheel, 24 feet diameter and 12 tons weight; steam-valves of double-beat type. The pumps are vertical, situated in the bottom of a deep pit, and when used run at a speed of 18 revolutions per minute. The pump-valves are circular, 14 inches diameter, free lift, two in inlet and two in outlet; each weighs 78 pounds.

The Dean pumps are condensing duplex, two cylinders to each, 34 inches diameter by 26 inches stroke, operating two plain piston-plungers 18 inches diameter by 26 inches stroke, run at a speed of 30 revolutions per minute, and connected with a jet-condenser 4 feet square. The air-pumps, one to each engine, are 15 inches diameter by 12 inches stroke. Steam is admitted by slide-valves operated by eccentrics. The daily duty of these pumping-engines averages about 40,000,000 foot-pounds, but has been run as high as 63,000,000 on a duty trial with poor soft coal, a duty of 60,000,000 having been guaranteed by the makers. They are placed in the bottom of a deep well, and are shown in the accompanying cut.



DEAN PUMP.

There are eight boilers, in two batteries of four each, 16 feet long by 44 inches in diameter, with thirty-six $3\frac{1}{2}$-inch tubes in each, burning poor bituminous coal, and maintaining an average pressure of 60 pounds for the Dean engines and 90 pounds for the old horizontal engine. Their evaporation is given at $8\frac{1}{4}$ pounds of water to 1 pound of coal. The old engine cost without boilers $57,000, and the two sets of Dean amounted to $26,000. The former is now used only as an auxiliary. From the pump-house the water is forced into the reservoir through 420 feet of 36-inch cast-iron main under a pressure of 119 pounds.

The stand-pipe, which is connected with this main near the reservoir, is a plain cylinder of wrought iron 36 inches diameter, $\frac{3}{16}$-inch thick, and 115 feet high, with one inlet and one outlet 36 inches diameter. The whole is inclosed in a square brick tower 15 feet square at base by 5 feet at top, and cost complete $42,000. By an arrangement of by-pass and valve the water may flow from the stand-pipe into the reservoir or supply-mains direct.

The reservoir is 185 feet square in plan, and is divided into two sections by a masonry wall 3 feet thick. Its upper section is but 11 feet in depth, while the lower is 21 feet. The walls are of masonry, perpendicular on the inner face, sloping 12 vertical to 1 horizontal on the outer face, and 4 feet thick at top; capacity about 2,250,000 gallons. Bottom of clay covered with masonry. There are two effluent-pipes, one from each division, which unite into one supply-main immediately after leaving the reservoir.

There were, in December, 1880, $42\frac{1425}{5280}$ miles of cast-iron distributing mains from 18 inches to 3 inches in diameter, supplying water to 5,000 takers, with a consumption of 3,736,000 gallons per day. Two hundred and five hydrants are in use, of which perhaps fifty are Matthews' patent and the rest are of home manufacture.

The first cost of the works was $100,000, and total to date $1,371,789. The total expenses and receipts from 1832 to 1880, inclusive, interest not included, were, receipts, $1,215,227; expenditures, $1,371,789. The annual expense of maintenance and repairs amounts to about $26,000.

The city engineer, W. F. Forster, has control of the water-works.

LOUISVILLE, KENTUCKY.

Louisville is on the south bank of the Ohio river, 387 miles above its mouth, and contains a population of 123,758. Its interests are commercial and manufacturing. Chief among the latter establishments are distilleries, breweries, tobacco factories, and founderies. The site of the city is a level plain about 70 feet above low water in the river. The streets are very regular.

Under the auspices of a private corporation a water-supply was introduced in 1860 by pumping from the Ohio river at a point about 1½ mile above the city limits. The city, having purchased a large portion of the shares in this corporation, is represented in the management of the works.

The water is taken from the river by a wrought-iron pipe 50 inches in diameter, with its outer end supported in a crib. The latter is rectangular, of timber filled with stone, and is 70 feet long, 32 feet high, by 12½ feet wide. Its end is parallel with the current, and contains the inlet-opening, which is protected by a coarse grating, finer ones being placed in the pump-wells.

The mouth of this inlet is 5 by 12 feet and 1 foot below low-water level. From here the water is conveyed 300 feet to the two pump-wells beneath the engine-house. They are rectangular in plan, of masonry, and 8 by 22 feet by 11 feet deep.

Owing to defective construction of the crib, stoppages occurred from the clogging of this inlet-pipe in 1866, 1874, and 1877; two from the deposition of sediment in the inlet and one from floating leaves.

From the wells the water is pumped into a stand-pipe by two Cornish beam-engines, designed by Theodore R. Scowden in 1860, and built by Roach & Long, of Louisville. A sectional view of them is given in *Knight's Mechanical Dictionary*, p. 1828, and a view of the valve-gearing in front of the cylinders is also shown.

The engines are alike, and have: Diameter of steam-cylinders, 70 inches; stroke, 10 feet; diameter of pump-plunger, 36 inches.

The steam-valves are of the ordinary Cornish double-beat type. There is but one plain plunger to each engine, and one receiving water-valve, of the Harvey & West double-beat pattern. The discharge-valves are of the same pattern but smaller, and 36 in number. The former is 43 inches and 32 inches diameter of seat, with a lift of 1⅜ inch, and the latter are 6 inches, the lift being ⅜ inch.

The engines are run at an ordinary speed of 8 revolutions per minute, and are of 7,500,000 gallons capacity each. The record of their work during 1878 and 1879 is given below:

		1878.	1879.
Number of pumping days		365	363
Average pumping time per day	hours	18.23⅓	20.06⅔
Total pumping time per year	do	6,656.25	7,281.25
Total number of engine- and pump-strokes per year		3,142,395	3,501,198
Average number of strokes per minute		7.87	8.014
Coal consumed	pounds	4,739,639	4,964,335
Ashes, cinder, and clinkers	do	326,861	383,635
Quantity of water pumped each year	gallons	1,649,757,375	1,838,128,950
Average height of water in stand-pipe above low water in river	feet	152.00	152.75
Average stage of river above low water	do	6.65	5.57
Average head against pumps	do	145.35	147.18
Annual engine duty in pounds of water raised 1 foot high per 100 pounds of coal		42,269,481	45,449,566

Each pump has a jet-condenser 32 inches in diameter and 9 feet long, with an air-pump 32 inches in diameter by 6½ feet stroke. The total cost of the engines and boilers was $117,000. The daily duty averages about 45,000,000 foot-pounds. There are two batteries of three boilers each, of the old Cornish pattern, with one 45-inch flue. They are 30 feet long by 6 feet diameter, with an evaporative power of 8½ pounds of water per pound of coal. The latter is the best quality of Pittsburgh coal, and the pressure averages 25 pounds.

From the pumps the water passes into the stand-pipe a few feet from the front of the engine-house. This is a wrought-iron tube 48 inches in diameter and 132 feet high. Its top is 196 feet above low-water level, and the base of the foundation is 22 feet above the same plane. Thickness of metal, from ½ to ¼ inch. Thirty feet below the top there are four 20-inch pipes branching from the main one by means of elbows and expansion-joints, and descending to the base. The water overflowing from the central 48-inch pipe into these four pipes supplies the distributing main direct, without passing through the reservoir. The whole construction is encased in an ornamental wooden tower painted white. The cost was about $50,000. In detail it is described in the eighteenth annual report.

Of distributing reservoirs there are two, one built in 1879, the other in the early stage of the construction of the works. The latter is situated 3,650 feet to the south of the pumping-station. It is 178 by 375 feet at water-line, with a total depth of 24 feet, and depth of water of 19½ feet, the top of which is 141 feet above low water in the river. It is divided into two basins by a wall. Through the center of this wall the 30-inch force-main from the pumps rises and discharges the water from a bell-shaped end. A second 30-inch main discharges into an influent-chamber, and passes into the reservoir over a weir. The banks slope 1½ to 1 on the inside. Springs in the bed and under the embankment have caused considerable trouble from time to time. In 1876, a sediment of 5 feet depth which had accumulated in the course of several years was removed by a system of hydraulic mining, the same as at Saint Louis.

The needs of the city requiring a new one, the Crescent Hill reservoir was completed in 1879. It is 2¼ miles from the stand-pipe, with which it is connected by two lines of 30-inch cast-iron force-main. In 1879, the first and second pumping-mains to the old reservoir were almost entirely taken up, and the supply-mains from the two reservoirs were connected. The water-level in the Crescent Hill basin is 175 feet above low water, and, therefore, 34 feet above the level of the old basin. It is trapezoidal in plan, with embankments of earth faced with 3 feet of puddle; slopes of 1½ to 1 interior, and 2 to 1 exterior; 21 feet width of banks at top; a division-wall rising to the level of the banks, also 21 feet wide, and having both faces puddled. The total depth of the basin is 24 feet, and its capacity 100,000,000 gallons. The average head of water in the city is 110 feet, and the maximum 175 feet.

The dimensions of the two basins forming this reservoir are as follows, measured on the bottom: One basin is rectangular in plan, 589½ feet long by 518 feet wide; the other is trapezoidal in plan, 580 and 640 feet long and 518 feet and 530 feet wide. There are three chambers in the well beneath the reservoir gate-house, the influent- and effluent-chambers being united into one. The first takes the water from the pump-mains and discharges it over weirs into either basin at will, regulated by stop-gates. The second chamber is a dry well containing stop-valves, etc. The third delivers into the three supply-mains, 48, 48, and 36 inches, respectively, in diameter. Along the foot of the embankments, opposite the gate-house side of the reservoir, is constructed a brick conduit, 60 inches diameter, with a 60-inch stop-gate, where it passes through the division embankment, and terminating in an open end half way to the end of each basin. This is merely a circulating pipe. Water is forced by the pumps into one basin, and, crossing to the opposite side, passes through the circulating pipe into the other basin, thence back to the effluent-chamber. It is a very economical arrangement.

The subjoined table shows the length of pipes of all sizes for the supply and distribution of water, laid up January 1, 1880:

	Linear feet.
48-inch	474
43-inch	49
36-inch	12,786
30-inch	45,047
20-inch	25,378
16-inch	37,038
12-inch	6,409
10-inch	10,386
8-inch	30,755
6-inch	165,889
4-inch	227,276
3-inch	12,919
2-inch	291
Total feet	574,697
Total miles	108.844

About 3 miles additional pipe was laid in 1880, making 111 miles in all.

The consumption averages daily about 5,500,000 gallons, delivered to 7,600 consumers.

There are in use 30 hydrants, mostly of Matthews' patent, and about 350 fire-cisterns. The latter are circular brick wells beneath the surface of the streets, containing from 100 to 500 barrels of water each, and so arranged that a fire-engine suction-hose can be readily dropped into them. They are connected with the mains by a short tap.

Three hundred meters of the Worthington, Union, and Gem type are in use.

The cost of the works as originally constructed amounted to $837,000, which has now increased to a total of $3,905,000, as shown in an itemized statement given below:

Cost of works to January 1, 1880.

Real estate	$101,033 16
Inlet and river works	38,279 00
Engines and pumps	187,784 92
Engine-house, chimneys, etc	125,180 52
Stand-pipe and tower	50,035 76
Coal-houses	6,415 41
Improvements around buildings	23,364 66
Reservoir No. 1	89,411 13
Crescent Hill reservoir	569,631 70
Roads, fences, and improvements of grounds	47,152 39
Pipe system	1,937,460 03
Pipe-way	82,740 78
Contingent expenses	60,964 05
Expenses conducting works	572,528 15
Harrod's Creek Precinct bond tax	13,050 00
Total	3,905,031 66

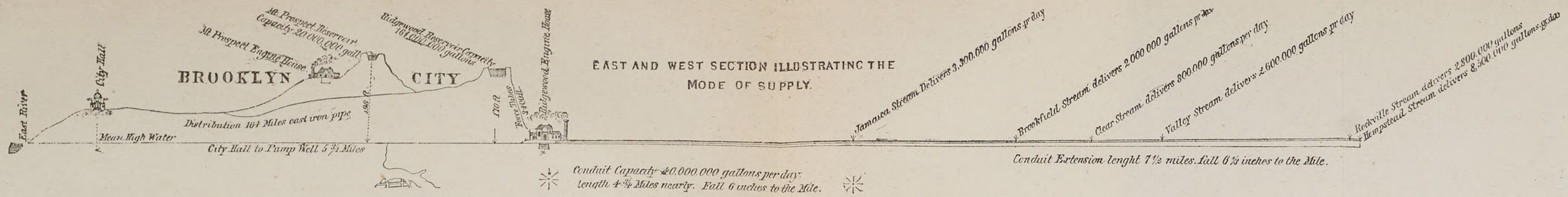
The cost of maintenance and repairs for 1880 was about $42,000.

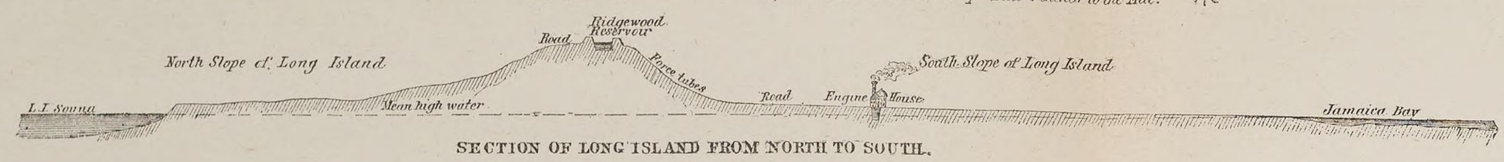
The annual cost of maintaining works, and revenue for 1879 is as follows:

Interest on city water bonds, paid by city	$82,580 00
Interest on company water bonds, paid by water company	55,080 00
Total interest on bonds per annum	137,660 00
Expenses conducting the works per annum	40,218 37
Repairs and contingent expenses per annum	5,856 00
Total cost of maintaining works per annum	183,734 37
Revenue per annum	176,097 45
Excess of cost for maintaining works over revenue	7,636 92
Interest on bonds per 1,000 gallons of water distributed	$7\frac{29}{100}$
Expenses conducting works per 1,000 gallons of water distributed	$2\frac{13}{100}$
Repairs and contingent expenses per 1,000 gallons of water distributed	$0\frac{31}{100}$
Total cost per 1,000 gallons of water distributed	$9\frac{73}{100}$
Revenue per 1,000 gallons of water distributed	$9\frac{33}{100}$

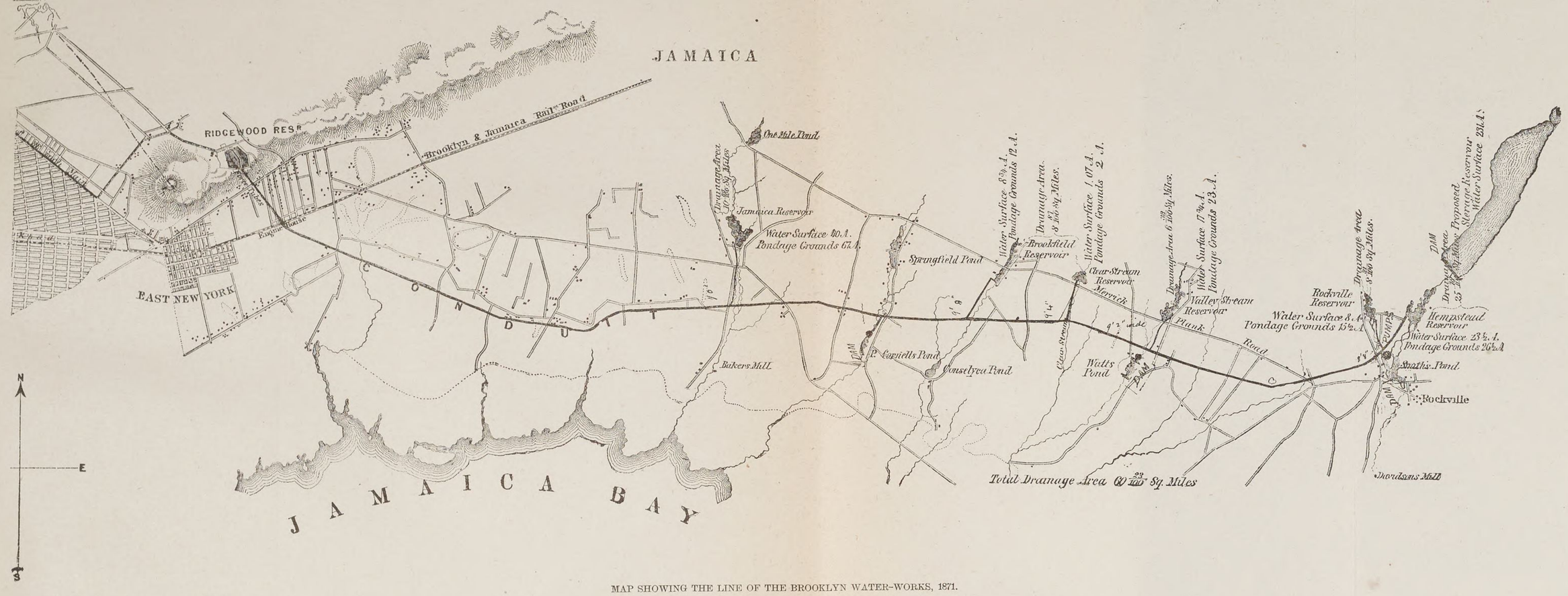
The water as derived from the Ohio river is almost always very turbid, but after subsidence in the reservoir is much improved. No analysis of it seems to have been made at any time.

The works are at present in charge of Charles Hermany, C. E., as chief engineer.





SECTION OF LONG ISLAND FROM NORTH TO SOUTH.



MAP SHOWING THE LINE OF THE BROOKLYN WATER-WORKS, 1871.

6.—PUMPING DIRECT TO RESERVOIRS.

BROOKLYN, NEW YORK.

Brooklyn, with extensive commercial and manufacturing interests, and situated on the easterly bank of the East river, has an area of 20 square miles. It is generally elevated above the river from 80 to 90 feet, about 1½ or 2 miles of its water-front being a bluff 70 feet high, overlooking New York harbor. Toward the northern limits the land slopes away to nearly tide-level.

Its population is 566,663. There is little regularity to the plan of its streets. Toward the eastern limits of the city, parts of it attain an elevation of 190 feet, upon which the distributing reservoir for high service is situated.

In 1856 a supply of water was introduced into the city by a combination of pumping and gravity. The supply is derived from a succession of small ponds and lakes at distances of from 4 to 12 miles from the eastern limits of the city, which ponds and lakes draw their supply from the great water-shed of Long Island. This is a ridge, extending from one end of the island to the other and sloping gently toward the ocean, of sand and clay soil, containing bowlders. Hempstead Plains, lying in the western end of this slope, furnishes the chief part of the water used for supply. They are sand and gravel, from 5 to 15 miles wide. On a ridge which separates Hempstead Plains from the city, is situated the storage or the Ridgewood reservoir, at an elevation of 170 feet.

The ponds and lakes mentioned average from 4 to 8 acres in extent, and are from 8 to 10 feet deep. They have been formed by obstructing the flow of the various small streams by earth dams, through which small branch conduits convey the impounded waters to a large main conduit, extending from the most easterly or Hempstead reservoir to the pump well at the engine house. The different streams are as follows:

Streams.	Miles from ferry.	Elevation above tide.	Estimated flow.
		Feet.	*Mil. gals.*
Jamaica creek	13.75	8	5.00
Nostrand's creek	15.25	13	1.50
Springfield creek	15.75	10	0.25
Simonson's creek	16.00	15	4.00
Shaw's creek	17.25	9	0.50
P. Cornell's creek	18.50	12	2.00
Hine's creek	20.25	9	2.00
L. Cornell's creek	21.00	10	8.00
Seeley's creek	23.00	6	0.25
Baldwin's creek	23.25	1	0.25
Millburn's creek	23.75	7	2.00
Smart's creek	25.50	18	5.00

After the construction of the dams a dry-season measurement of the streams as consolidated gave the following minimum flows:

	Million galls.
Jamaica stream delivery	3.3
Brookfield stream delivery	2.0
Clear stream delivery	0.8
Valley stream delivery	2.6
Rockville stream delivery	2.8
Hempstead stream delivery	8.5

The ten ponds formed and in use at present have a total drainage area of 60.23 acres, and are known as follows:

Basin.	Distance from city line.	Water-surface.	Depth.	Capacity.	Elevation of dam above tide.
	Miles.	*Acres.*	*Feet.*	*Mil. gals.*	*Feet.*
Jamaica reservoir	5.404	40.00	8	.....	7.90
Springfield pond	.....	.....	.....	.....	.....
Cornell's pond	.....	.....	.....	.....	.....
Brookfield reservoir	7.906	8.75	7	.....	15.40
Clear Stream reservoir	8.771	1.07	6–7	.....	11.50
Valley Stream reservoir	9.708	17.78	.....	.....	12.80
Watt's pond	.....	.....	6–7	.....	.....
Rockville reservoir	12.343	8.00	.....	.....	12.05
Smith's pond	.....	.....	.....	.....	6.05
Hempstead reservoir	12.39	23.50	5	.....	10.60
Storage reservoir	.....	231.00	15	1,000	29.00

The conduit which collects and conveys the water of the above ponds is 12.25 miles in length, with a fall of 6 inches per mile for the first 4.75 miles from the pumps, and 6.25 inches per mile for the remaining distance. Through it the water flows by gravity to the pump-well, whence the engines force it into Ridgewood basin.

The works, therefore, as built in 1856–'62, consist of: (1) The 10 supply ponds shown in the map, with corresponding dams; (2) The masonry conduit and branches; (3) The pump-wells, engine-house, engines, etc.; (4) Force-mains to Ridgewood reservoir; (5) Ridgewood reservoir; (6) The supply and distribution mains; (7) The high-service pumping-works; (8) Force-main to high-service reservoir; (9) Mount Prospect or high-service reservoir.

The dams forming the ponds are usually embankments, with a puddle-wall through the center in most cases, and all riprapped with stone, generally rubble in cement. The Jamaica dam, a type of most of the rest, is 15 feet wide at top, 12 feet high; inside slope, 2 to 1; outside, 1½ to 1. Puddle-wall 13 feet high in center and terminating 3 feet below the level of embankment tops. It is 9 feet thick at bottom and 4½ feet at top. The main portion of the embankment is of sand and gravel. On the inner face, at a height of 6 feet from the bottom, there is an offset 6 feet wide. Above this the inner slope is riprapped with rubble in cement. The water-surface is 4 feet below the top of the embankment. The riprap is 9 inches thick, laid upon 3 inches of gravel. At one end of the dam is the sluiceway into the conduit, and the overfall or waste-weir. The latter is a masonry wall about 8 feet high, terminating 4 feet below top of dam, about 5 feet thick at top, with an upstream batter of 1 to 4 vertical; downstream batter, 1 to 5. This wall of cement masonry, 21 feet long, is contained between two wing-walls of masonry, 3 feet thick at top and batter as before, forming a water-way 21 feet wide. The approach and apron or waste-way in front and behind the overfall are thus constructed: Long 8- by 10-inch timbers are laid parallel with the dam, 3 feet 2 inches apart; upon these, at right angles, a flooring of timbers is laid and fastened to them. On the downstream side, which takes the force of the overfalling water, this flooring is paved with 12 inches of loose stone blocks. Beneath the front face of the stone overfall, and at the lower end of the paved apron, sheet-piling has been driven 12 feet deep. Two waste-culverts, 2 by 3 feet, pass through the base of the overfall. Between the wing-wall of the overfall and the end of the dam is a masonry sluiceway, with an entrance 5 feet square, connecting with the branch conduit, 3 feet 6 inches square, to the main conduit line. The mouth of this sluiceway is provided with wire screens.

The cleared bottom of the pond proved to be clean sand. The following table gives a few details of the other ponds:

Pond.	Area of pondage grounds.	BRANCH CONDUITS.		OVERFALL.		Waste-sluice.	Conduit sluice.
		Length.	Diameter.	Height.	Width.		
	Acres.	*Feet.*	*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Jamaica	67.33	2,937	42	7.50	21	2 by 3	5.0
Brookfield	11.88	2,877	24	8.80	15	2 by 3	4.5
Clear Stream	1.80	1,980	24	3.00	8	2 by 3	4.0
Valley Stream	23.20	2,103	30	8.25	18	2 by 3	5 0
Rockville	15.50	1,872	30	8.25	18	2 by 3	4.0
Hempstead	26.58	.....	.....	8.00	24	2 by 3 2 by 3	6.0

A gate-house covers each sluice-gate, and the branch conduits are circular, of brick, and each provided with a gate at its junction with the main. The ponds are each protected about the margins with sand embankments.

The conduit is built of masonry, the side walls being of gneiss rock, 20 inches thick, with a 4-inch lining of brick-work. Its bottom lies on an average 28 inches below water-level, which much increased the cost. Short lengths, where it passed through marshy ground, were built upon piles. The invert is of brick, 8 inches thick, laid in 8 inches of cement, and the arch of the same, with a radius of 5 feet and thickness of 1 foot. Of the main portion, from the pump-well to Jamaica pond, the width of the inside is 10 feet and the height from invert to crown of arch 8 feet 8 inches. From here to Valley Stream pond its height is only 8 feet 1 inch, and its width is diminished by 4 inches above the junction of each branch conduit. Between Valley Stream pond and Rockville reservoir this width is 8 feet 8 inches, and from thence to Hempstead it is 8 feet 2 inches.

The versed sine of the invert of the smaller portion of the conduit is increased to 12 inches, and the thickness of the invert lining is doubled. The minimum depth of earth over the conduit arch is 4 feet; it never runs full. Within 2,000 feet of the pump-well, 30 openings 4 by 2 feet and about 50 feet apart, were left at the springing line of the arch on the east side. They are from 4 to 5 feet below ground-water level, and by gauge in 1859 showed an infiltration of 1,402,000 gallons per 24 hours.

To prevent undue filling of the pump-well when the engines are not in operation, three waste-gates have been provided, two of which are located about 2 miles from the pumps.

The conduit terminates in an arched basin of masonry 5 feet thick at sides and 2½ feet at bottom, 10 feet wide by 52 feet long, standing at right angles to the conduit. This basin is separated from the pump-well by a 5-foot masonry wall, which has four openings, 4 by 6 feet each, into the pump-well, which lies parallel with it. The latter is one long trough of masonry, 60 feet long by 10 wide, divided into two compartments by a wall with gates, so that two of the engines may be operated while the others are being repaired.

The engine-house is a plain brick building, 68 by 80 feet, with two wings, each 44 by 60 feet, and a coal-shed and boiler-house attached.

There are in operation three beam-engines of 15,000,000 gallons capacity each. Nos. 1 and 2 were built by Woodruff & Beach, of Hartford, in 1859. No. 1, which was remodeled in 1871, has two lifting-pumps, one beneath the steam-cylinder and the other at the opposite end of the beam, and connected by a pipe 3 feet in diameter with the pump-well. The two are so connected that while the piston of the lower pump under the cylinder is rising and discharging its contents into the force-main through the other pump, the piston of the latter is descending with its valves open. Its principal dimensions are as follows: Diameter of steam-cylinder, 80 inches; diameter of working pump-barrel, 36 inches; diameter of auxiliary pump-barrel, 54 inches; stroke of all, 10 feet.

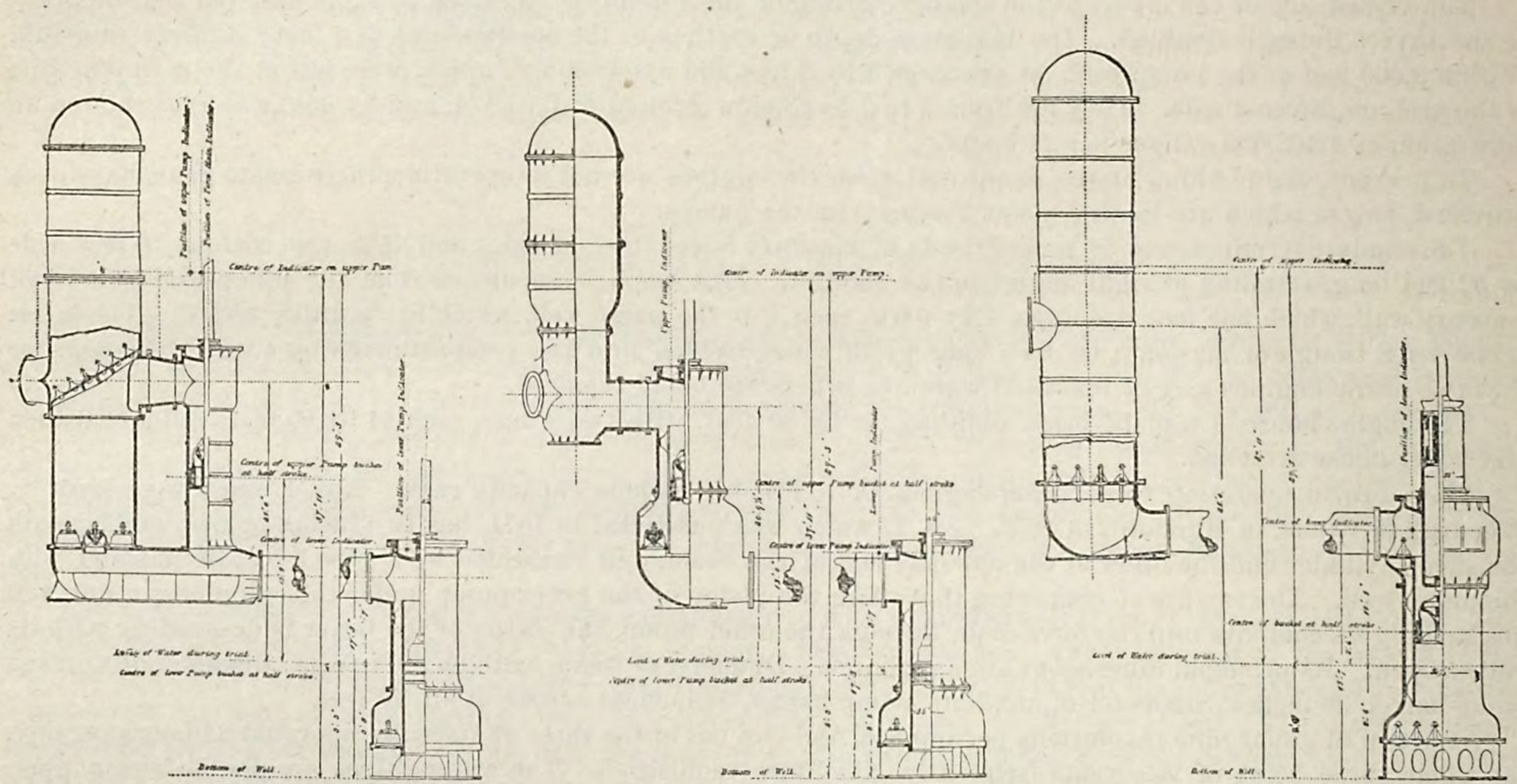
It is run at about nine revolutions per minute, and two out of the three engines are operated 24 hours per day, the whole three being of late years frequently called into requisition. The water-valves are double-beat puppet-valves, 12½ by 20½ inches diameter of seats. There are eight in suction and eight in the delivery of lower cylinder and seven each in upper pump. Lift of valves, 2 inches. The engine is condensing, and operates a double-acting air-pump 36 inches diameter by 60 inches stroke. A spray-condenser connected with it is 4 feet diameter by 8 feet high. Further details of engines Nos. 1 and 2 are given in Kirkwood's *Report on the Brooklyn Water-Works*, from which many details have been taken.

Engine No. 2 is like the first, with steam-cylinder 90 inches diameter, and pumps 36 inches diameter, with a stroke of 10 feet. A fly-wheel was added to No. 1, but No. 2 has none, being operated with a heavy counterbalance. The guaranteed duty, while forcing the water through 3,450 feet of 36-inch force-main into Ridgewood reservoir, a lift of 164 feet, was 600,000 pounds per pound of coal. It works at 10½ revolutions per minute. Engine No. 3, erected by Hubbard & Whittaker, of Brooklyn, in 1869, is a double acting condensing beam-engine, 85 inches diameter of cylinder, with a Thames Ditton pump, 51 inches diameter of bucket beneath the cylinder, and a fly-wheel at the opposite end of the beam; capacity, 14,000,000 gallons. The steam-cylinder, which is steam-jacketed, is 7 feet 1 inch diameter by 10 feet stroke; plunger, 3 feet 8 inches diameter. There are twenty foot-valves, each 11¼ inches internal diameter by 2-inch lift, thirteen valves in upper plate, and one bucket-valve of double-beat type, 40¼ by 26¾ inches diameter of seats. The condenser, of jet-pattern, is 4 feet diameter by 5 feet 7 inches high, with an air-pump 36 inches diameter by 54 inches stroke. Figures 1, 2, and 3 show the pumps of the respective engines. To furnish steam for the three engines there are two batteries; in all, twelve boilers. Seven of them are 24 feet long by 8 feet diameter each, and were made by Henry Smith, of Brooklyn. They are drop-flue boilers, with four flues each, 16 inches diameter by 15 feet long, and are operated under 22 pounds pressure, with anthracite coal on the grate. The remaining five boilers, made by Hubbard & Whittaker, are 27 feet long, 7 feet diameter, with grates 6 feet long, 3½ feet wide, and twelve 8½ inch flues, 13 feet 7 inches long each; drop-flue.

From the pump-house to Ridgewood reservoir, a distance of 3,511 feet, there are three 36-inch force-mains of cast iron, one for each pump. They do not pass through the embankments of the reservoir, but deliver into a chamber, their outlets being about on a level with high water. The object of this arrangement was to give access to their whole length without breaking into the bank. There is a check-valve in each main.

Ridgewood reservoir, situated to the north of the pumping station, is polygonal in outline, with a division-wall through the center, dividing it into two basins of 11¾ and 13¾ acres area water-surface, respectively, and total capacity of 161,000,000 gallons. The side embankments are irregular in height, from 8 to 30 feet. They are of earth, of 20 feet width at top, with a puddle-wall through the center, commencing 2 feet below the bank-level, at a thickness of 3 feet and increasing by steps, one foot in thickness for each 5 feet in depth, to a total of 6 feet at the

base and 22 feet in total height. A layer of puddle 2 feet thick extends from the base of the wall under the entire bottom of the reservoir. The faces of the banks are covered with 6 inches of gravel, upon which a stone riprap is laid 12 inches thick in cement, with occasional open joints to allow the water to be drawn out from behind the riprap, in the event of the lowering of the water-level in the reservoir; slopes, 1½ to 1. Total depth of water, 20 feet. High-water surface, 4 feet below embankment-level. Height of same above engine-well, 163 feet. The division embankment is similar to the above, but 15 feet wide at top and 3 feet high above high-water level. The influx-chamber of masonry is 19 by 28 feet and 9 feet deep below high-water, from which the water passes into either or both compartments over a weir 4 feet thick and 3 feet below high water.



No. 1. No. 2. No. 3.

PUMPING ENGINES, BROOKLYN, N. Y.

The efflux-chamber at the opposite end of the division-wall is of masonry 4 feet thick. It is square in plan, the dry-well being 25 feet long by 10 feet wide. There are arrangements for three 36-inch iron supply-mains, only one being laid as yet. It is fitted with a stop-gate in the dry-well. Two masonry channels 10 feet wide extend from the dry-well front-wall into the reservoir, one into each compartment. In each of these, about 20 feet from the dry-well, is a 4-foot masonry partition from top to bottom, and in these are four openings to admit water from the reservoir. Two of the four are each 4 by 4 feet square, and 5 feet below high water, and the other two are each 4 by 3 feet and located at the bottom. A drain-pipe from each compartment extends through these partitions and the dry-well and are discharged without the reservoir.

The distribution, which is chiefly carried out in cast-iron pipes, is in length and sizes as follows:

Water-pipe laid for the supply and distribution of water to January 1, 1881.

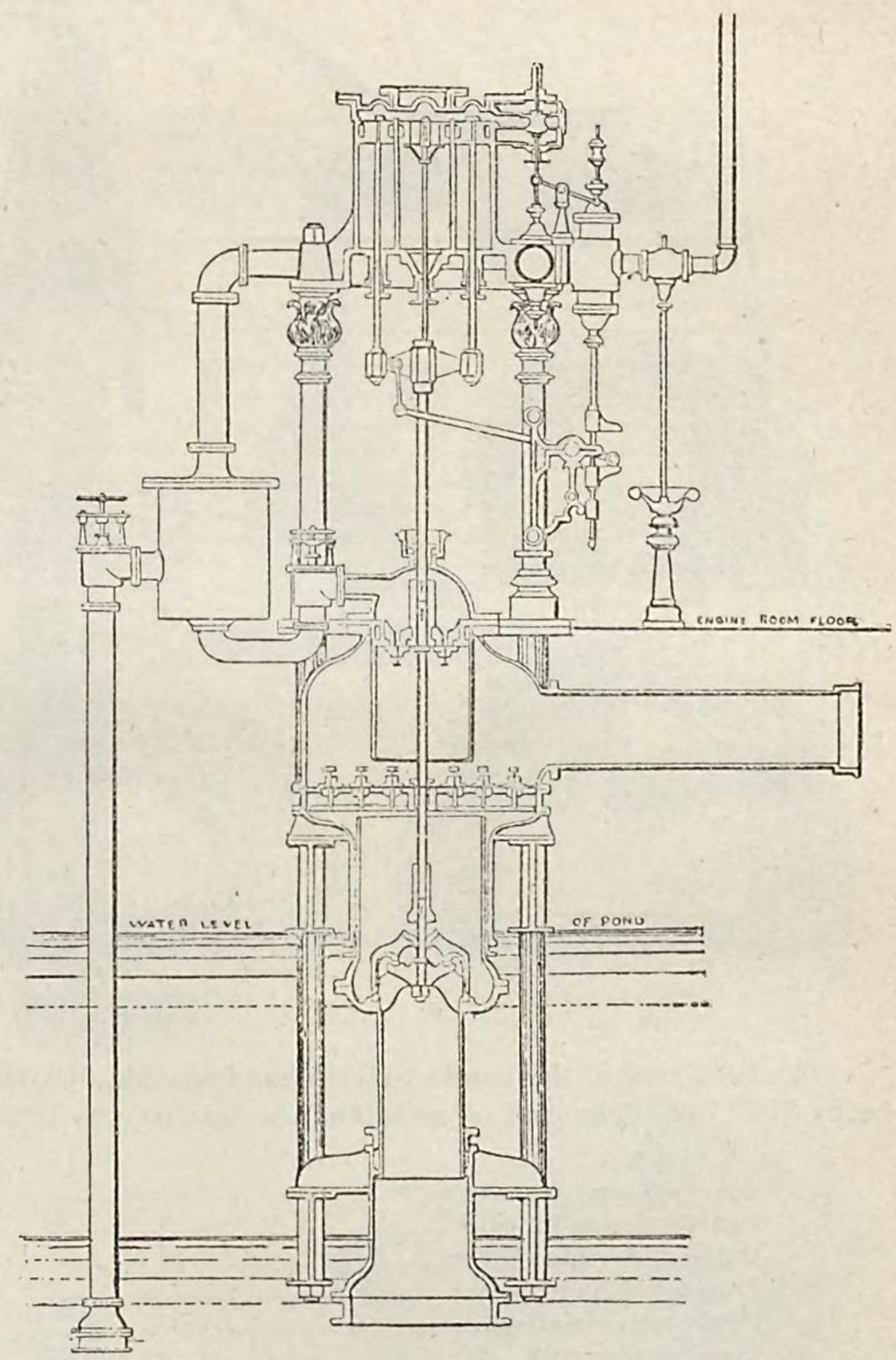
	Original distribution, cast iron.	Original distribution, cement.	Total length in use.	Total length in use.
	Feet.	*Feet.*	*Linear feet.*	*Miles.*
4-inch	.....	.....	2,903	0.549
6-inch	328,786	9,182	1,209,953	229.157
8-inch	157,413	993	327,764	62.077
12-inch	63,366	.....	165,490	31.340
20-inch	22,636	.....	65,369	12.380
30-inch	25,193	.....	25,193	4.771
36-inch	26,397	.....	26,971	5.108
48-inch	.....	.....	33,483	6.343
Length (original distribution, cement)	.....	.....	.....	120.069
Total length	.....	.....	.....	351.723

To supply the highest portions of the city, high-service works were built, consisting of pumping machinery and Mount Prospect reservoir. These pumps draw their supply from the 36-inch supply-main from Ridgewood reservoir, at a distance of 26,062 feet from it, by means of a branch main at Washington and DeKalb avenues, from 20 to 30 inches diameter, and 4,600 feet long.

The engine-house, a plain brick building with stone trimmings, is 40 by 60 feet, with boiler-room 40 by 40 feet, and has space for only two engines, only one being occupied. The engine, which pumps only during the night, so as to prevent diminution of head in the mains for the low service, is a crank and fly-wheel engine, with cylinder 24 inches diameter by 54 inches stroke, and two pumps with cylinders 20¼ inches and stroke of 41½ inches. This engine, which supplies Mount Prospect reservoir, and is located 122 feet above tide-water, has a capacity of 3,000,000 gallons per day, and actually supplies 2,500,000 gallons through the 20 inch force-main, 2,052 feet long, to the reservoir. Its duty at the test-trial in 1862 was 640,577 foot-pounds per pound of coal, 600,000 foot-pounds being guaranteed. Steam is furnished by one drop-flue boiler, 18 feet long, 6 feet diameter, with four upper flues, 13 inches diameter by 11 feet long, and nine lower ones, seven of which are 9 inches and two 7 inches diameter each, and each 9 feet 3 inches long.

Full details of the engine are found in W. E. Worthen's *Report on Brooklyn Water-Works*, page 136, appendix 1.

Mount Prospect reservoir, used for the high service, supplies that portion of the city south of Atlantic street, and is located on Flatbush, Underhill, and Grand avenues, President and Sackett streets. In plan it is square, with one corner cut off, approximately 330 by 340 feet on bottom. High-water surface is 198 feet above mean tide and 28 feet above high water in Ridgewood reservoir. Its high-water surface covers an area of 3.43 acres, with a capacity of 20,036,558 gallons. Depth, 20 feet. The banks are 20 feet wide, and slope 1½ to 1 inside and out. The bottom and banks are lined with puddle 2 feet thick. Upon the slopes is a layer of 3 inches of concrete over the puddle, and the bottom and slopes are further protected by an 8-inch covering of brick laid in cement. The bottom slopes from all sides toward the outlet into the drain-pipe. The force-main discharges into the bottom of an influent-chamber at one corner of the reservoir, 6 by 14 feet by 12½ feet deep below the top of the embankments. The masonry is 4 feet thick, and the force-main 20 inches diameter. From 5 feet 7 inches above the bottom of the influent-chamber a 30-inch pipe passes out into the inner bank, and, extending downward, just beneath the puddle-facing, passes through the latter near the toe of the slope into the reservoir, supported in the latter passage upon a pier of masonry. This pipe passes out of the influent-chamber into the reservoir at high-water line. A single overflow-pipe, 12 inches diameter, extends from high-water surface in the external wall of the influent-chamber to the street-sewer.



The effluent-chamber, situated at the opposite corner of the reservoir, is about 35 by 50 feet, of masonry 3 feet thick, and forms but a single chamber or dry well. Through it pass a 30-inch supply-pipe, with stop-valve, and a 12 inch drain-pipe, also stopped by a gate. The former passes through the bank through brick walls, to prevent percolation through the banks. In front of the mouth of this pipe, in the toe of the slope, are two screens, in appropriate chamber.

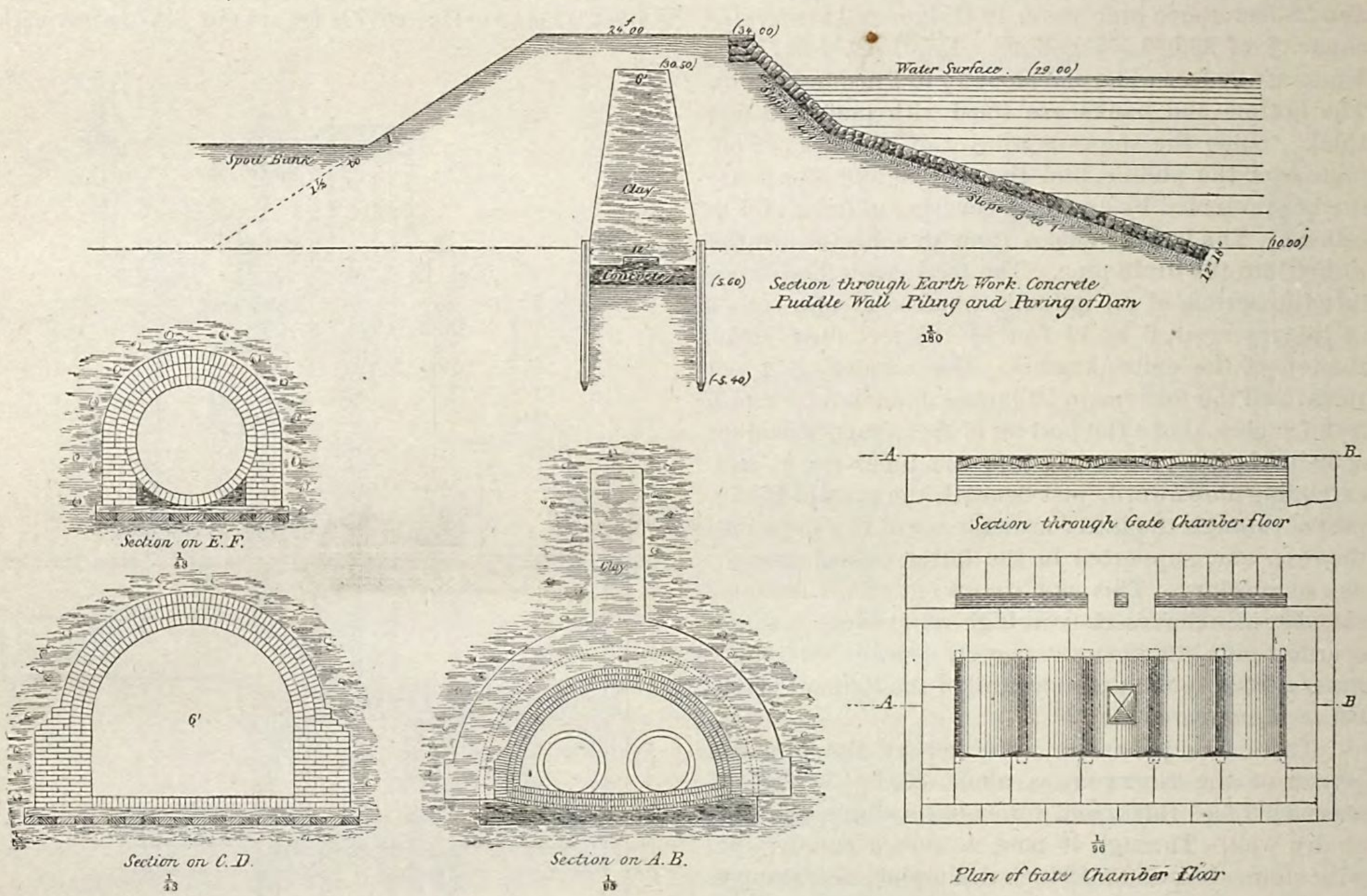
Of the distribution system no pipes over 20 inches diameter are tapped. There are 60,555 taps in the system, which includes Brooklyn city, and Governor's island, in the New York harbor. The consumption averaged in 1880 about 30,745,000 gallons per day, and reached in January nearly 48,000,000 gallons. The result has been at times a scarcity of water in the city.

The supply from Hempstead reservoir and the water-shed from which Brooklyn's supply is derived proving inadequate to the demand, three wells have been dug, at Smith's, Watt's, and Cornell's ponds, and pumps have been placed at the former, delivering into the main conduit, with machinery in readiness for use at the two latter. These wells are each 50 feet in diameter, with a total depth of 20 feet, and depth of water usually 15 feet. They are built of brick, with vertical tie rods through the lining, and sides 2 feet thick. The bottom is sand, and not closed. The curbs upon which the linings were sunk are 4 feet high. These wells are estimated to yield 2,500,000 gallons per day of exceedingly pure water. The soil is entirely white sand. The water pumped from them is forced through 16-inch mains into the conduit. The pumps have a capacity of from 3,500,000 to 5,000,000 gallons per day.

The following table gives details of the meters in service January 1, 1881:

Kind of meter.	⅝-inch.	¾-inch.	1-inch.	1¼-inch.	1½-inch.	2-inch.	3-inch.	4-inch.	6-inch.	Total.
Worthington	219	....	140	....	5	41	11	12	....	428
Gem	265	10	93	....	5	65	9	22	2	471
Crown	156	....	.....	1	....	1	....	....	....	158
Ball & Fitts	1	....	.....	....	....	.....	....	....	....	1
Brooklyn	.....	...	2	....	....	6	....	6	....	14
Union	.....	....	.....	...	....	.....	....	....	1	1
Nassau	2	....	4	....	...	1	2	....	....	9
Eagle	3	....	.....	....	....	.....	....	....	....	3
Total	646	10	239	1	10	114	22	40	3	1,085

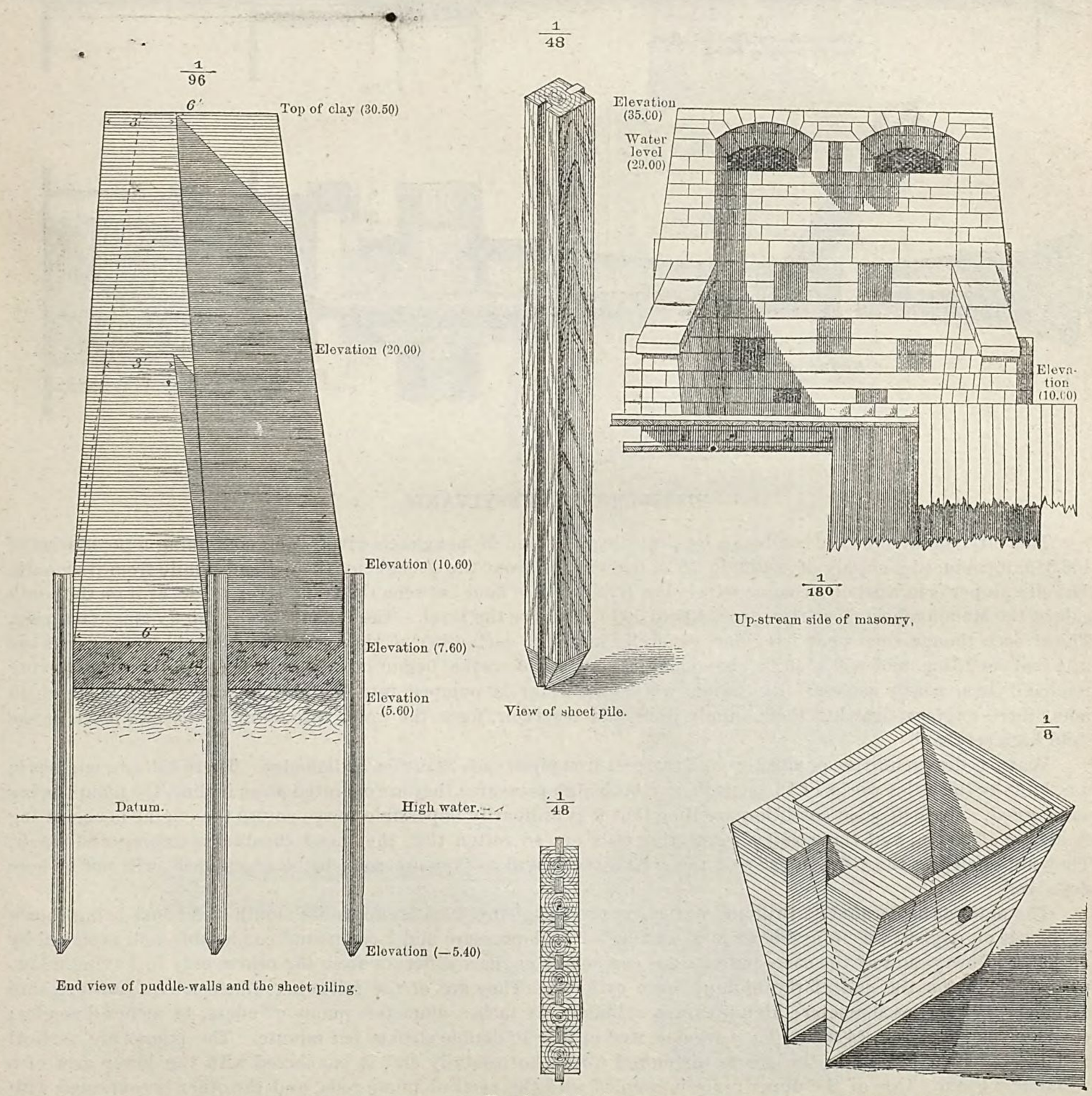
In the distribution mains there are none less than 6 inches diameter, and in the city there are 2,874 fire-hydrants.



The total cost of the works to date has been $11,379,500, and total receipts $14,231,370, the last yearly receipts being $977,700. The cost of maintenance for the year 1880 was $272,321, itemized as follows:

Salaries:	
Commissioners, registrars, etc	$35,015 96
Distribution and repairs	48,610 87
Ridgewood engine-house	33,796 46
Prospect engine-house	4,940 43
Ponds and conduits	2,776 56
Prospect reservoir	1,940 29
Ridgewood reservoir	1,458 02
Smith's pond	3,064 04
New reservoir	999 97
Supplies:	
Distribution and repairs	15,085 04
Ridgewood engine-house	38,571 76
Prospect engine-house	7,393 30
Ponds and conduits	4,461 45
Prospect reservoir	2,001 61
Ridgewood reservoir	544 45
Smith's pond	2,521 32

New reservoirs	$1,412 59
Printing and stationery	2,530 98
Taxes	2,061 22
Tapping mains	4,200 60
Office expenses	1,148 13
Contingencies	22 50
Maps, registrars' department	250 00
Resurvey pipe district	2,090 05
Ridgewood reservoir enlargement	110 35
Coal at pumping-stations	54,300 12
Additional water-supply	1,013 00
Pumping engine No. 4	
Cleaning Smith's pond	
Gauging streams beyond Hempstead	
Total	272,321 07



End view of puddle-walls and the sheet piling.

View of sheet pile.

Up-stream side of masonry.

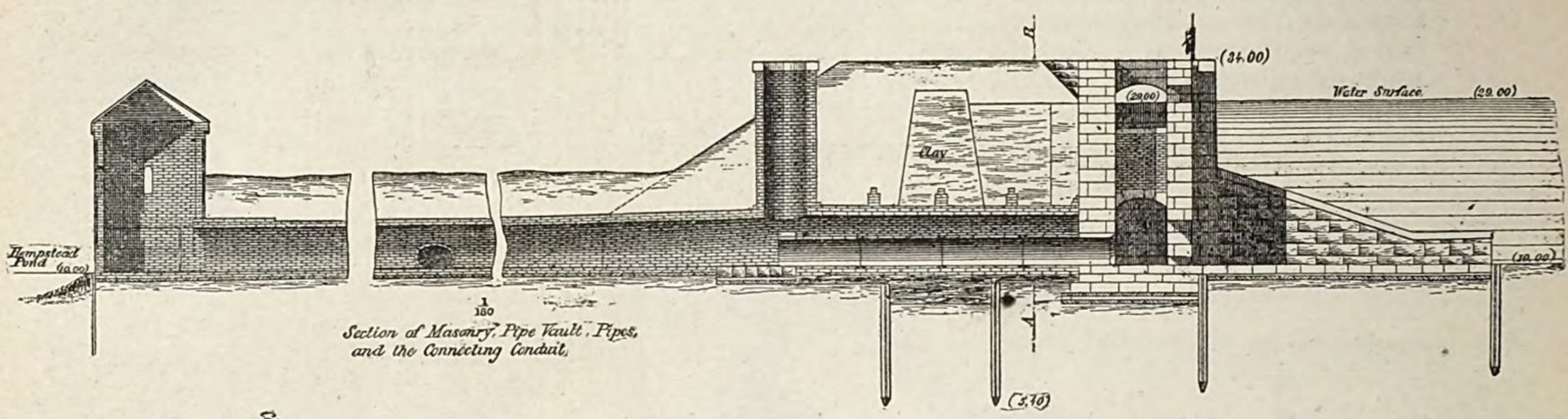
Top view of sheeting.

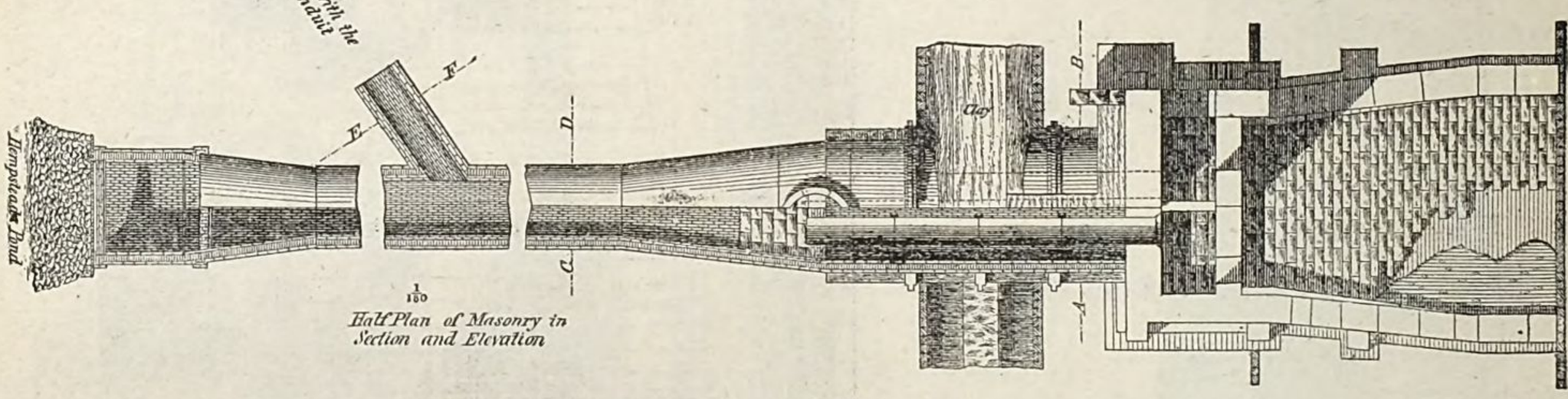
Cast-iron shoe for piling.

The works are under the charge of the department of city works, Mr. Robert Van Buren, chief engineer.

Hempstead reservoir having insufficient storage capacity, a new one is in course of construction and nearly completed. Details of the dam are given in the cuts. It is situated a short distance to the east of the old one, and has a drainage area of 25.78 square miles, with a water-surface of 231 acres, capacity of 1,000,000,000 gallons, and average depth of 15 feet.

Rates for water per meter measurement are $7\frac{3}{4}$ cents per 100 cubic feet.





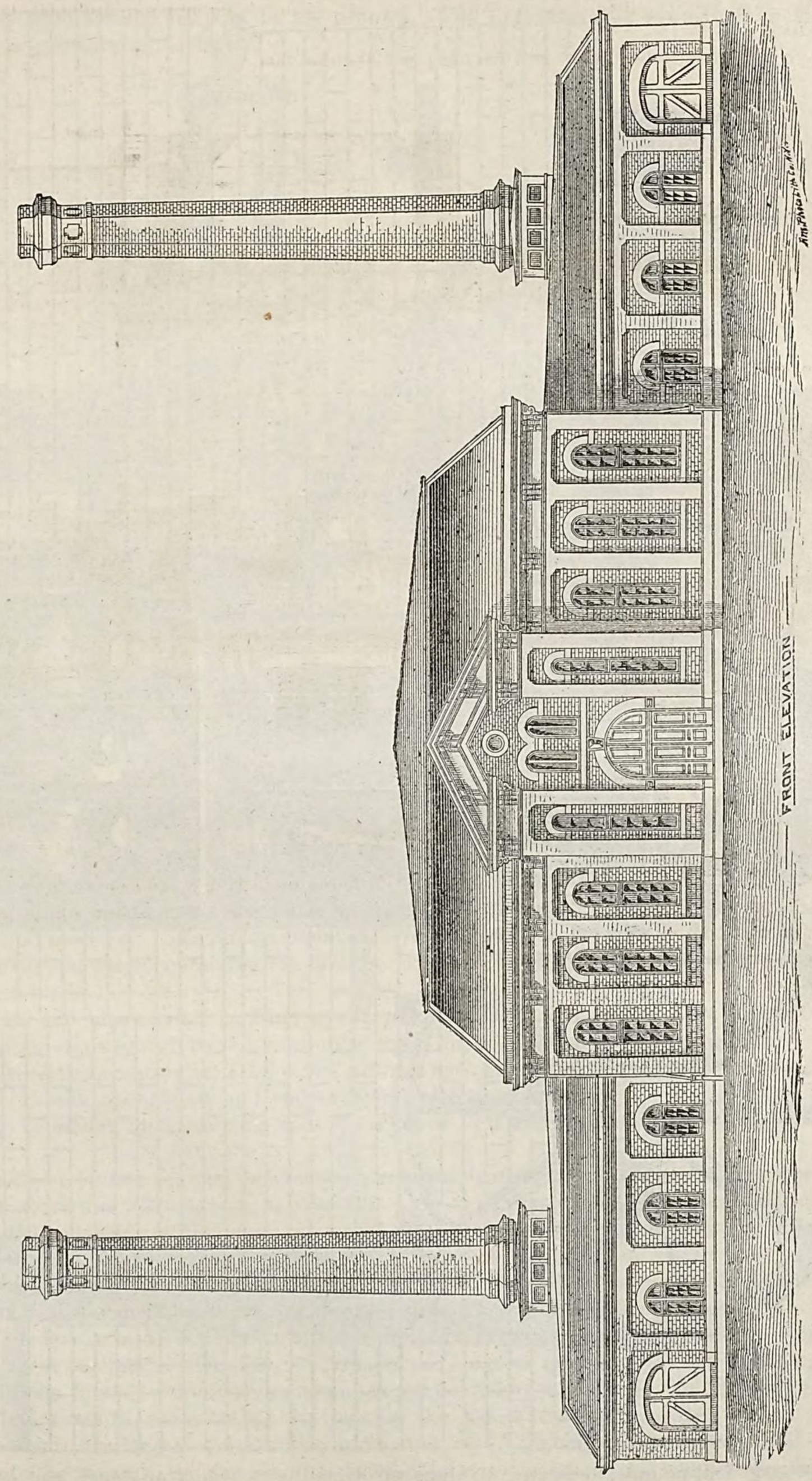
PITTSBURGH, PENNSYLVANIA.

This city, situated at the confluence of the Allegheny and Monongahela rivers, and containing a population of 156,389, introduced a supply of water in 1824, deriving it from the Allegheny river about a mile from its mouth. The city proper is located on a comparatively low-lying strip of land between the two rivers; a part of it on the south side of the Monongahela river rises from 400 to 500 feet above the level. The industries are chiefly manufacturing. The streets, though somewhat irregular, generally intersect each other at right angles. The old water-works are in a bad condition, and will soon be abandoned, a new set of works, begun in 1872 and completed in 1878, having rendered them nearly useless. By the old works the water is pumped into Bedford Avenue reservoir, at which point three engines, drawing their supply from this reservoir, force the water into an upper basin, known as the "old high service".

Water is drawn into the pumps through two cast-iron pipes each 29 inches in diameter. There are two engines in use, built by the Atlas works of Pittsburgh, and both high-pressure; they are operated on an incline, the pumps being submerged. In such poor condition are they that it is ordinarily impossible to see across the engine-house, owing to escape of steam, and the wooden connecting-rods are so rotten that they need constant watching and repair. They are known as the "Hercules" and the "Sampson", and as they are soon to be abandoned, will not be here described.

The new works, located at Brilliant station, on the Allegheny, 10 miles above its mouth (the house being shown in the cut on page 91), contain 4 horizontal engines—2 high-pressure and 2 compound condensing—all designed by Joseph P. Lowry, and of the same pattern, the compound engines differing from the others only in having a low-pressure built on the end of the high-pressure cylinder. They are of the following dimensions: Low-pressure cylinders, 106 inches diameter; high-pressure cylinders, 64 inches diameter; pump-cylinders, 44 inches diameter; stroke of steam-piston, 14 feet. They are operated at 9 or 10 double strokes per minute. The pumps are vertical and located in a pit, while the steam piston-rod works horizontally and is connected with the lower arm of a triangular beam. One of the upper arms is coupled with the vertical pump-rods, and the other is connected with

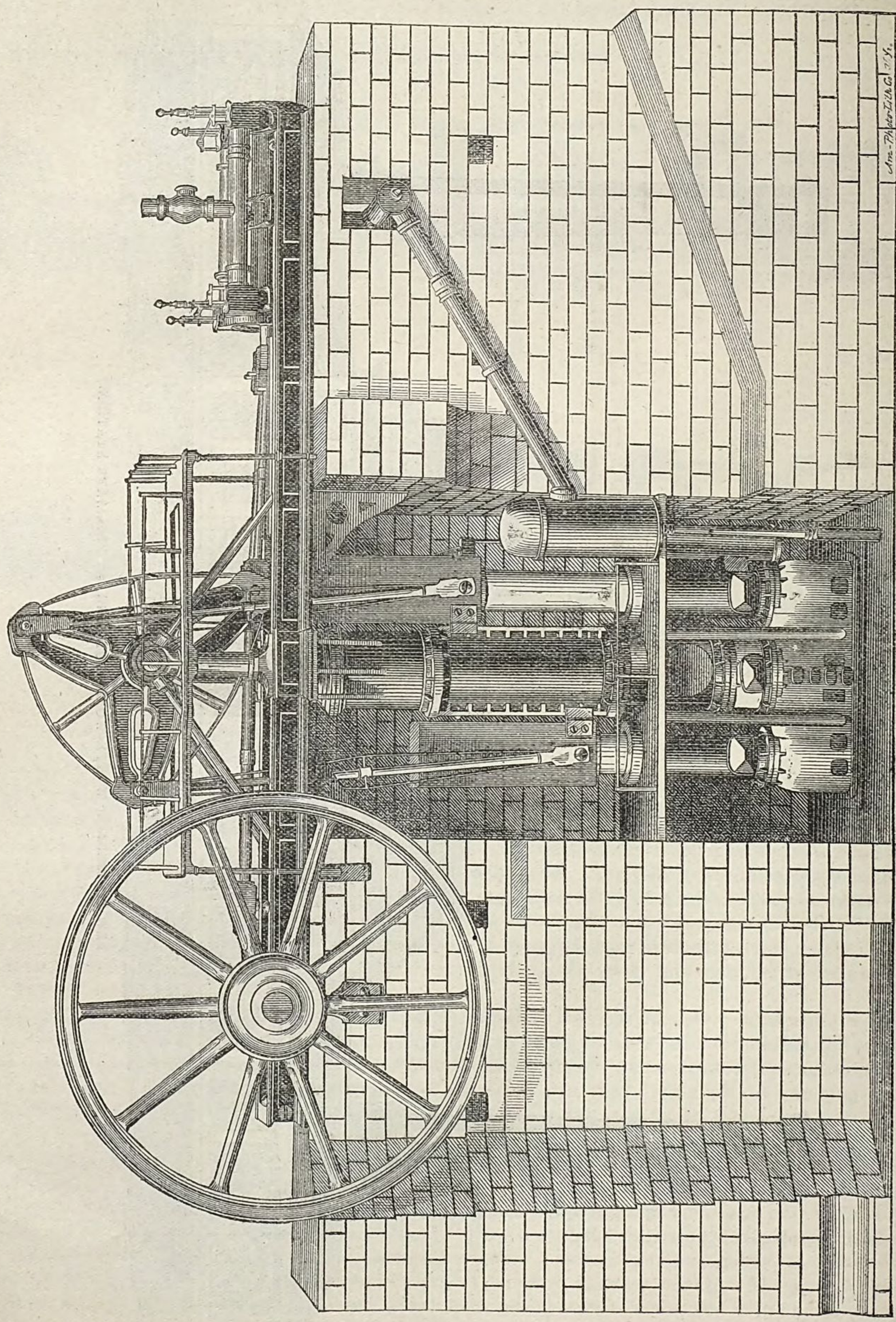
a heavy counterbalancing weight. The puppet steam-valves are operated by cams from the main shaft. There are two plain solid-plunger pumps to each engine, with four receiving and four discharge valves to the plunger, each weighing from 200 to 220 pounds, 21 inches diameter, with a lift of $1\frac{3}{4}$ inch of brass, disk-shaped.



NEW PITTSBURGH WATER-WORKS BUILDING, AT BRILLIANT STATION.

Two engines are generally run at the same time, and from 12 to 24 hours per day, the high-pressure at 7 or $7\frac{1}{2}$ revolutions per minute, with 120 pounds of steam and 165 pounds pressure on the pumps. Jet-condensers, 10 feet

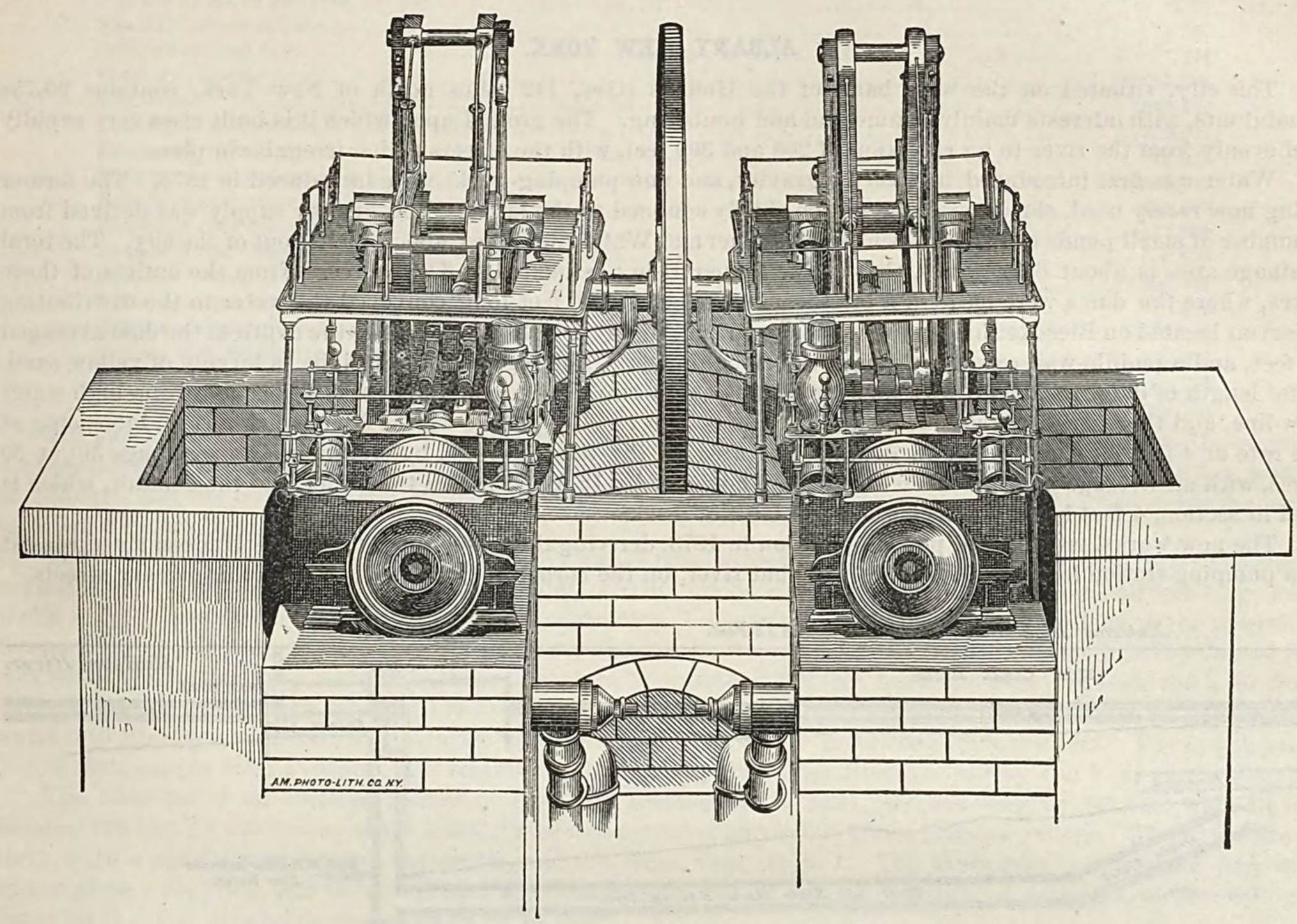
7 inches long by 13 feet 3 inches outside diameter, are used with the compound engines, the air-pumps being 24 inches in diameter by 11 feet stroke. The guaranteed speed was 10 double strokes per minute, which rates the engines at 20,000,000 gallons capacity. No careful duty-trial has ever been made, but an experimental trial showed



a duty of about 46,000,000 foot-pounds, according to data furnished by the chief engineer, and calculated on an amount of fuel not including that required to kindle the fires. The duration of the test was 12 hours.

There are 32 double-flue boilers, each 40 inches diameter by 32 feet long, with flues 14 inches diameter, and burning soft coal. The evaporation has never been computed.

The engines have cost to date about $750,000, and have required expensive repairs. They are the largest horizontal engines used for the purpose in the country. The following cuts show their construction before the addition of the low-pressure cylinders.



From this pumping-station the water is forced through 3,840 feet of 50-inch cast-iron main, under a head of 365 feet, into Hiland reservoir. The pumping-station is shown in the cut on p. 91, and consists of a plain rectangular brick building, with two wings containing the boilers. It is located on the edge of the river, its foundations being much below water-level.

A basin on the hill immediately in front of the pumping-station, and known as the Brilliant reservoir, was begun in 1872, at an elevation of 208 feet above the river, but abandoned before completion.

The Hiland reservoir, containing 117,651,000 gallons, with an area of 19¾ acres at flow-line, is situated 365 feet above the river. It is in excavation and embankment, with slope of 1½ to 1 inside and out, faced on the former with stone riprap 15 inches thick, resting upon 5 inches of broken stone, underlaid by a puddle-facing of 2 feet thickness.

A 20-inch main on Centre avenue, 4,309 feet long, is connected with the 30-inch main from Hiland reservoir. From the former 505 feet of 15-inch pipe conveys the water to the pump-well of the engine-house on Belle avenue. This is Herron Hill pumping-station for high service. The water thus taken from the Hiland main is forced through 1,250 feet of 12-inch main into the Herron Hill reservoir, with a lift of 275 feet.

A pumping-engine, taken from the Bedford Avenue works, has a capacity of 1,500,000 gallons per day. It is operated by a battery of three boilers taken from the Forty-fifth Street works.

Herron Hill reservoir is a rectangular embankment reservoir, 305 by 170 feet on the bottom, 24 feet deep to the level of the top of the banks, with a layer of 5 inches of concrete covering the whole bottom, the banks sloping 1½ to 1 inside and out, having a 2-foot facing of puddle, protected by from 6 inches to 1 foot of broken stone, covered with a riprap of cut stone 15 inches thick. Its capacity is rated at 10,000,000 gallons.

Cast-iron mains to the length of 113 miles, and 4, 6, 8, 10, 12, 15, 20, and 30 inches in diameter, respectively serve to distribute the water to the amount of 16,000,000 gallons per day to the inhabitants, the number of takers being unknown, but the consumption per head being estimated at 100 gallons per day. There are 912 hydrants in

use. The works originally cost $110,000, and this amount had been increased in 1872 to $1,627,800. The cost of the new works amounts to about $5,000,000. The expense of maintenance and repairs in 1880 was $130,000. From 1872 to 1879 the expenses were $792,190 and the receipts $2,117,450. Direct-pressure works, erected in 1870 at Forty-fifth street, containing three small engines, are now abandoned, as the new works have rendered them of little use.

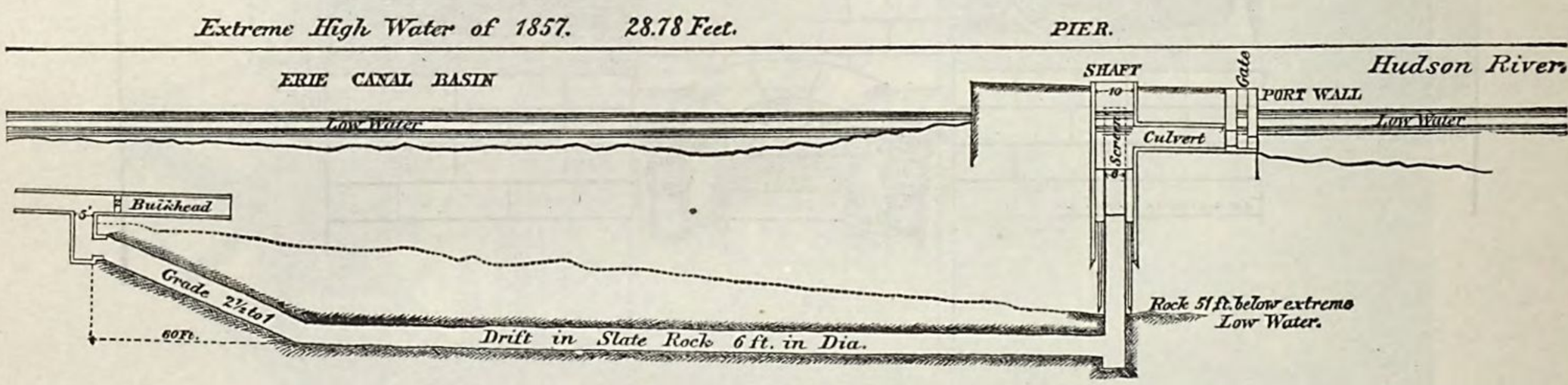
Details of the Bedford Avenue reservoir were not obtainable.

ALBANY, NEW YORK.

This city, situated on the west bank of the Hudson river, 142 miles north of New York, contains 90,758 inhabitants, with interests mainly commercial and lumbering. The ground upon which it is built rises very rapidly and evenly from the river to an elevation of 200 and 300 feet, with the streets rather irregular in plan.

Water was first introduced in 1850 by gravity, and new pumping-works were introduced in 1873. The former being now rarely used, the description will be chiefly confined to the latter. The gravity supply was derived from a number of small ponds or lakes known as Rensselaer and Watervliet lakes, about 3 miles out of the city. The total drainage area is about 8,455 acres, that of the former being estimated at 3,218 acres. From the outlets of these lakes, where the dams were located, a brick conduit about 15,000 feet long conveyed the water to the distributing reservoir located on Bleecker hill, in the westerly part of Albany. In Rensselaer lake the depth at the dam averaged 15 feet, and a puddle-wall extends through the embankment. The region in the vicinity is largely of yellow sand. Total length of dam, 1,400 feet, with no overfall or waste-weir. The top of the dam is 8 feet above the high-water flow-line, and the slope of banks inside and outside is 2 to 1. The puddle-wall is 8 feet thick at top, increasing at the rate of 4 feet for each 10 feet in depth. The area of the lake is stated by McAlpine (Report, page 50) at 39 acres, with an average depth of 16 feet. A gate-house 14 by 18 feet contains the outlet into the conduit, which is oval in section, 4 feet high by 3 feet wide, and built of brick.

The new works, erected and put in operation in 1873, deriving the water-supply from the Hudson river, consist of a pumping-station located 950 feet west of that river, on the corner of Quackenbush and Montgomery streets.



ALBANY WATER-WORKS—SECTION OF TUNNEL AND SHAFT.

On the eastern face of the river pier, 80 feet wide, is a gate-chamber. From this a culvert extends eastward to the shaft in the center of the pier. From the foot of the latter a rock tunnel extends beneath the Erie Canal basin 275 feet, and thence to the engine-house is a brick tunnel 645 feet long. The inlet from the river was built in a caisson, with river opening 18 inches wide by 30 inches long, extending from the top of the pier to a depth of 20 feet, or 7 feet below low water in the river. This opens into a well of the same depth, 4 by 7 feet. From the bottom of this well a culvert, 8 feet in diameter and 42 feet long, extends to the shaft in the center of the pier. This shaft is 10 feet in diameter by 47 feet deep, with a brick wall, 16 inches thick at base, resting on a cast-iron shoe, and was sunk against great pressure. From the 47-foot level another curb, 7½ feet in diameter, was sunk to a total depth of 51 feet below low-water mark. Cast-iron cylinders, 6 feet in diameter and 1½ inches thick, of a total length of 26 feet, secure the curbs from the bottom upward.

At a depth of 6 feet below bed-rock a tunnel, 6 feet in diameter, extends 275 feet to the brick tunnel, the last 60 feet of it rising with a grade of 2½ to 1. In the brick tunnel, near the west side of the Erie Canal basin, a 6-foot shaft, provided with a manhole, is constructed, 40 feet deep, to give access to the interior of the tunnel. The remaining length of tunnel extends beneath Water and Montgomery streets and the Hudson River Railroad tracks to the pump-well beneath the engine-house. The latter is a plain brick building, 52 by 62 feet, in one corner of a plot of ground 105 by 140 feet, nearly the whole of which is covered by the coal-shed, boiler-house, and the remaining buildings.

In this building are located the pumping-engines, two in number, made by Paulding, Kemble & Co. They are condensing beam-engines, connected to the same fly-wheel, each 32 feet diameter; and air vessel, 29½ feet high by 66 inches diameter.

The steam-cylinders are 42 inches diameter by 11 feet stroke, admitting steam essentially after the manner of river-steamboat engines, the steam-valves being operated by cams and plug-rods. The average speed is 12½

revolutions per minute. The pumps have two plain plungers, each with a stroke of 7 feet and diameter of 22 inches. The length of time they are employed and particulars of their working may be seen from the annexed summary of operations during the year 1879:

Number of days' pumping	262.5
Number of hours' pumping	2,906.6
Number of hours pumping per day	11.06
Revolutions per minute	11.957
Revolutions per day	7,944
Total revolutions	2,085,334
Lift in feet	242.492
Velocity in force-main, in feet per second	3.00071
Friction in feet	15.351
Pounds of coal consumed in pumping	3,315,345
Pounds of coal consumed in heating buildings	164,649
Pounds of coke consumed in pumping	117,209
Pounds of coke consumed in heating buildings	6,800
Pounds of ashes, etc	383,701
Ashes, etc., per cent	10.682
Gallons of water pumped into Bleecker reservoir per pound of fuel	335.296
Gallons of water pumped into Bleecker reservoir per day	4,369,271
Total gallons of water pumped into Bleecker reservoir	1,146,933,700
Duty in foot-pounds	71,582,768

The suction- and discharge-valves are of the double-beat Harvey & West type. The capacity of the engines is guaranteed at 10,000,000 gallons, pumped into the Bleecker reservoir (a lift of about 242 feet above low water) in 24 hours, and the duty at 60,000,000 foot-pounds. The condenser is of the jet pattern, 36 inches inside diameter by 5 feet 5 inches high.

The actual duty obtained on an average in 1879 was 71,582,700 foot-pounds; cost of engines, $135,000. The steam is generated by five multitubular return-flue boilers, containing seventy-eight 3½-inch tubes each 10 feet long, with shells 6 feet diameter by 20½ feet long, and consuming 1 pound of coal to pump 268 gallons to the reservoir. Evaporative power unknown. From the pumping-station the water is raised 243 feet through 9,723 feet of 30-inch diameter cast-iron main—1⅜ inch thick to sustain pressures of 250 feet head and over; 1¼ inch thick for from 200 to 250 feet; 1 inch thick for from 150 to 200 feet, and the remainder ⅞ inch thick. This force-main delivers the water into Bleecker reservoir, from whence the lower portions of the town are supplied direct. The upper parts derive their supply from Prospect Hill reservoir, which is supplied from Bleecker hill by the high-service pumps.

The Bleecker is an earth-embankment reservoir, rectangular in plan, 660 feet long by 340 feet wide on the bottom, 720 feet by 400 feet at top of banks, with a capacity of 28,475,000 United States gallons. The banks are of earth, with a puddle-wall through the center, and the faces slope 1½ to 1. The inner face is riprapped part way up the slope with brick, and the remainder with stone, both laid in cement. Depth of reservoir, 15 feet to high-water level. The gate-house measures 10 by 16 feet.

From the northern corner of Bleecker reservoir a 24-inch main 1,390 feet long extends to the well of the high-service engines, located on New York Central avenue, corner of Third street. From here the engines force the water into Prospect Hill reservoir adjoining.

The pumping-works consist of the pump-house, boiler-house, coal-shed, chimney, and engineer's dwelling. The engine-house contains two compound beam-engines, designed by F. Rumpf, and built by the Quintard Iron Works, of New York, in 1877, of a daily capacity of 5,000,000 gallons each, and to do a duty of 75,000,000 foot-pounds at a cost of $30,000. They are both connected to one fly-wheel, as in the case of the low-service, 18 feet in diameter, weighing 18,800 pounds. Beams 18½ feet long between centers and 18 feet above floor. Steam-cylinders: high pressure, 11½ inches diameter; low pressure, 20¼ inches diameter; stroke of high-pressure pistons, 4 feet 10 inches; low-pressure pistons, 6 feet.

The steam is admitted through double-beat valves, operated by plug-rods and cams geared to the main crank-shaft. The condensers are of the jet pattern, 10 by 17 inches, and connected with air-pumps 12 inches diameter by 24 inches stroke. Actual trial has developed a duty in these engines of over 81,000,000 foot-pounds.

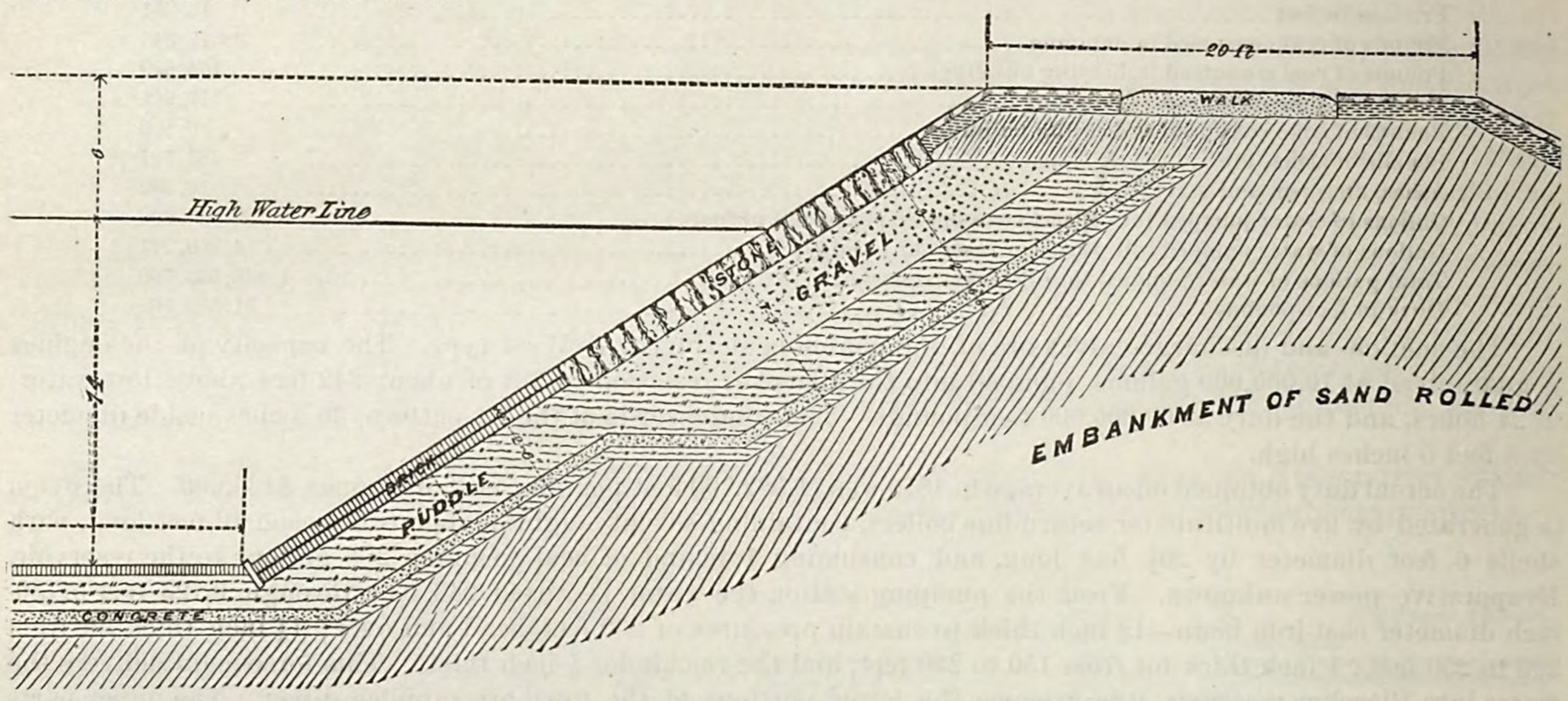
Each engine operates a bucket-and-plunger pump, with pump-cylinders 21¼ inches diameter, plungers 15 inches, and a stroke of 4½ feet. Each contains a butterfly foot- and discharge-valve hinged at the two sides and opening on a center line, with a lift of 4 inches and a diameter equal to that of the pump-cylinder and rubber seats.

The speed of the pumps averages twenty-five revolutions per minute. The accompanying record will show the work performed, etc., by the two engines during the year 1879:

Number of days' pumping	255
Number of hours' and minutes' pumping	$2,867^{h}\ 54^{m}$
Average time per day, in hours	11.23
Revolutions of engines per minute	23.968
Revolutions of engines per day	16,173.5
Revolutions of engines per month	4,124,342
Lift in feet	58.532

Pounds of coal consumed for pumping	332,826
Pounds of coal consumed for heating buildings	86,640
Total pounds of ashes, etc	63,117
Pounds of ashes, etc., per cent	15.04
Gallons of water pumped into Prospect Hill reservoir per pound of coal	1,439.755
Gallons of water pumped into Prospect Hill reservoir per day	1,312,844
Gallons of water pumped into Prospect Hill reservoir per month	479,188,160
Duty in foot-pounds	75,111,727

These engines derive their steam from a battery of four horizontal multitubular boilers, each 3½ feet diameter by 10 feet long, containing thirty-eight 3-inch tubes, consuming 1 pound of anthracite coal to pump 1,500 gallons into the reservoir, a lift of 55 feet.



Prospect Hill reservoir, which supplies the highest portions of the city under a total head of about 297 feet above high tide, is a rectangle in plan, with the four corners cut off, 360 by 161½ feet on bottom line, 20 feet deep, 420 by 220 feet at level of banks; slope, 1½ to 1 inside and 2 to 1 outside; capacity at high-water line (15 feet), 7,312,203 gallons, with an area of water-surface 1¾ acre; width of top of banks, 20 feet.

The construction of the embankments may be seen from the drawing. A 6-inch layer of puddle over the whole bottom, and extending up the face with one offset, is again covered with a 6-inch layer of concrete. Above this is a layer of puddle 18 inches thick on the bottom and 30 inches thick on the face of the bank. The offset begins at about half way up the slope and extends to the top. In this a depth of 36 inches of gravel overlies the last layer of puddle, and a riprap facing of stone 15 inches thick laid in cement. The bottom, and the slope for a distance of 8 feet up to the toe of the granite paving, are covered with brick on edge laid in cement.

The gate-chamber is 10 feet 6 inches by 6 feet 10 inches, situated on the westerly corner of the reservoir, and contains three pipes, one 12-inch drain-pipe 12 inches below the bottom of the reservoir, and two 24-inch pipes, both of which are used as supply-pipes. The drain-pipe is now used for the same purpose. A bridge connects the house with the top of the bank. The inlet- or force-main is 20 inches diameter, and conveys the water from the pumping-engines through about 325 feet of main, under a head of 55 feet over the top of the embankment at the eastern corner of the reservoir, whence it extends downward between the facing of stone and the underlying clay until it reaches the bench at the foot of the gravel, at which point it emerges through the brick riprap, and runs down along the face of the same out upon a stone apron 20 by 8 feet on the bottom of the reservoir. A 20-inch pipe around the foot of the outer slope connects the force- and supply-mains, and is controlled by a valve.

From both Prospect Hill and Bleecker reservoirs a system of supply-mains of cast iron 77⅓ miles long supplies the population of the city through mains of 20, 16, 12, 10, 8, 6, 4, and 3 inches, respectively, in diameter, with about 4,500,000 gallons per day. Tivoli lakes are said to supply about 2,000,000 gallons. The maximum head of water in the low service is 244 feet, and in the high service 55 feet.

The cost of the Prospect Hill reservoir and pumps and the whole system of water-works to 1880 was estimated at $800,000, and the cost of maintenance and repairs for 1879 at $57,350.

Of hydrants on the distribution mains there are 493. An analysis of the water from the gravity supply was made by Julius G. Pohle, M. D., of New York, in 1865, who found it to contain saline constituents, etc., in the proportion of 5$\frac{8}{10}$ grains to the gallon. These consist mainly of the following: Chloride of sodium, carbonate of soda, chloride of calcium, chloride of magnesium, vegetable organic matter, sulphate of lime, silicic acid, carbonate of lime, and carbonate of iron.

The works are at present controlled by Mr. George W. Carpenter, superintendent.

NEW HAVEN, CONNECTICUT.

New Haven contains a population of 62,882 inhabitants, and is situated upon New Haven bay. It is largely a city of residences, with mercantile and manufacturing pursuits. Topographically the city is rather flat, but it is surrounded on the north and west by hills of considerable size. The strata composing the bed and adjoining hills are largely of Triassic formation, with outcroppings of trap-rock. The streets are laid out more or less regularly on the rectangular plan, many being heavily shaded by large elms.

The water-supply, introduced in 1862 by the New Haven Water Company, is derived from four sources, chief among which is a small stream known as Mill river. Several artificial reservoirs west of the city, known as Wintergreen lake and Maltby ponds, furnish the remainder.

Mill river discharges into the sound. At a point about 3 miles north of the city the hills between which it flows approach to within about 400 feet of each other, and here the dam has been placed. The bed of the river is rocky and somewhat shelving. The drainage area of the stream is about 56 square miles, while the total water-shed of the ponds mentioned amounts to about 5 square miles. The dam mentioned has backed the water of Mill river for a distance of about 2½ miles, and the sheet thus formed is known as lake Whitney. The maximum flow of the river is estimated at about 12,000,000 gallons daily, and the quantity constantly stored is calculated at 500,000,000 gallons, with an average depth of 20 feet. The consumption, according to indicators, averages 5,000,000 gallons per day.

The dam is constructed of cement masonry, and is 500 feet in total length, with an inner core of concrete from the foundation to the water-line, 8 inches thick. The upstream face is protected still further by a gravel bank. The thickness of the dam at top varies somewhat at different points. At the overflow the length is 150 feet; height, 38 feet 8 inches; thickness at top, 11.62 feet; at base, 34.12 feet; batter of face, 2 to 12; of back, 7 to 12. In the eastern end the height is 36 feet; thickness at top, 8.58 feet; at base, 34.83; batter of face, 2 to 12; of back, 7 to 12. On the main dam, part first, height, 38.5 feet; thickness at top, 3.25 feet; at base, 25.70 feet; batter on face, 3 to 12; on back, 4 in 12. Part second, height, 38.5 feet; thickness at top, 6 feet; at base, 25.70; batter of face, 3 to 12; on back, 4 to 12. West wing, height, 5 feet; thickness at top, 3 feet; at base, 6 feet. The gates, screens, and pipe from reservoir to pump-house are located in the gate-chamber of masonry in the west wing. The gate is 4 feet square, opening into a wrought-iron pipe 4 feet diameter, at a height of 17 feet above the base of the dam. This pipe furnishes motive-power for the armory and manufactory of the Whitney Arms Company, immediately adjoining the dam; this company formerly owned the water-rights. The water stands in the lake at a depth of 17 feet above this pipe. The waste-weir and overfall are located in the eastern end of the dam, the gate of the waste-pipe below it at a depth sufficient to drain the lake.

The bed of the lake is composed largely of rocky and gravelly soil, no great amount of mold having been present, and the water is of remarkable purity, as will be seen by reference to the appended analysis.

A deficiency of supply sometimes occurs in mid-summer, owing to lack of capacity in the main supply-pipe.

The mean annual rainfall of the district is about 45 inches, and the source of supply is practically unfailing. The system of supply to the city is a combination of gravity and pumping. The latter is accomplished partly by a couple of overshot water-wheels located in the old pump-house, and driving two horizontal pumps, and partly by pumping machinery erected in 1870 and consisting of a horizontal engine driving two horizontal double-acting pumps, located in a separate stone building about 45 by 50 by 20 feet in size, situated between the lake and the distributing reservoir, with boiler-house 35 by 40 feet. The old pump-house and pumps are thus described by the former engineer: The house is a brick building 60 by 40 feet by 25 feet high. Two wheel-pits excavated in rock are each 35 feet by 6 feet 6 inches by 17 feet deep, connected by a water-way 30 feet 6 inches by 9 feet 6 inches by 17 feet deep. The tail-water passes under the foundation-wall into an arched culvert 8 feet high by 8 feet wide by 50 feet long, and thence through an open race into the river below the dam. The water from the lake, after leaving the screens in the pipe-chamber of the dam, passes through the 4-foot iron pipe surrounded by an arched brick culvert into two cast-iron tanks containing a series of gates. Cast-iron pipes connect these tanks with two cast-iron forebays as well as with the rear valve-boxes of the pumps. The forebays conduct the water through gates at various points to the wheels. The two wheels built in 1861 by the Farrell Foundery and Machine Company of Ansonia, Connecticut, are wood and iron back-pitch overshot, 30 feet in diameter. The buckets are of wrought iron, 6 feet long. The power is transmitted through a 100-cog driving-wheel 7 feet 11½ inches diameter, and a pinion of 43 cogs and 6 feet diameter to the pump-piston. The two crank-shafts are so arranged that either pump can be operated by either wheel, or one pump by both.

The two pumps are each single-cylinder horizontal with a diameter of 16 inches and stroke 5 feet, connected with two air-vessels 7 by 3 feet each. Each pump has a capacity of 52¼ gallons, and is driven at 12 to 12½ double strokes per minute. The wheels are run under a head of 34 feet 8 inches, and are calculated to raise 1 gallon of water 115 feet high to the reservoir with the expenditure of 5 gallons of water.

The water from these pumps is raised through 3,100 feet of cast-iron 16-inch main, with two check-valves, to the Sachem Hill distributing reservoir.

The steam-pumping machinery, built in 1870 by the Yale Iron Works of New Hampshire, was intended to assist the foregoing in particularly dry seasons, and is occasionally used in winter, and to a considerable extent in summer. The engine is a horizontal fly-wheel single-cylinder condensing engine of 26 inches diameter and 4 feet stroke. When pumping, it is run at 55 revolutions per minute, and is calculated to pump 320 gallons of water 115 feet high with 1 pound of anthracite coal. It was erected to supply 6,000,000 gallons, and has frequently reached 6,125,000 gallons per 24 hours, using 4 tons of coal for the purpose. The valve and cut-off motion is given by eccentric rods from the main shaft, and the old-fashioned slide-valve is employed.

A battery of three return tubular boilers, of Boston make, furnishing steam under a pressure of 40 pounds, are 20 feet long, with thirty-three 4-inch tubes in each. To this engine, by gear-wheels, are connected two sets of double-acting piston-pumps, one on each side. They are geared down to run at a velocity of 12½ double strokes to 55 revolutions of the fly-wheel.

The pump-pistons are plain, 21½ inches diameter and 5 feet stroke, operating a pair of flap-valves at each end of the cylinder at every stroke, one suction and one discharge, with a lift of 6 inches. They discharge into a force-main 24 inches in diameter, of wrought iron and cement, extending uphill to the Sachem Hill reservoir, a distance of 1,800 feet, under a head of 95 feet. Air-vessels are connected with the pumps at the engine-house and a siphon-condenser 24 inches in diameter. The duty of the engine has never been ascertained. This engine-and-boiler house is of the rudest character within and without.

The Sachem Hill reservoir is situated on the summit of Sachem hill at an elevation of 129 feet above high water, and a short distance from the steam pump-house (exact distance unknown). It is elliptical in plan, and divided into two compartments.

The sides are partly earth embankment and partly excavation. The inner slopes are puddle-faced, 18 inches thick, and a layer of same thickness covers the bottom. Concrete 4 inches thick is laid upon this, and the slopes are covered with a 12-inch riprap of stone in cement. The total depth is 23 feet, and the water-line is maintained at 19 feet. Dimensions on the water-line, 488 by 244 feet; inner slope 1 to 1, and outer 1½ to 1; width of banks at top, 10 feet; capacity, 10,000,000 gallons. The influent-chamber is located at the east end of the partition-wall of the reservoir; it is divided into two compartments, so that the force-main empties into the first, and the water passes thence directly into either or both divisions of the reservoir by means of 12-inch iron pipes laid through the other compartment on which the valves and gates are situated, or it can pass through a 16 inch cement-lined wrought-iron pipe laid in the partition-wall of the reservoir directly to the effluent-chamber.

The dimensions of the effluent-chamber are: foundation, 28 by 24 feet by 3 feet deep; walls, 6 feet thick at bottom, and 2 feet 6 inches at top; division-wall forming the two chambers, 10 by 6 feet by 18 feet 7 inches deep.

The effluent-chamber has a depth of 20 feet 1½ inch, and is otherwise a duplicate of the influent, with similar screens, etc.

From the water-works to the city there is laid one 16-inch cast-iron main, 1½ mile long, three 16-inch wrought-iron and cement pipes of 3 miles total length, and 9 miles of 12-inch pipe of same material. The distribution is accomplished through 102 miles of pipes 4, 6, 8, 10, 12, and 16 inches, respectively, in diameter, and mostly cement-lined wrought iron.

Considerable lengths of a patent pipe made by D. G. Phipps, the present engineer, are used, and seem to give entire satisfaction. There are in the city of New Haven some remarkable cases of interior corrosion, 16-inch pipes reduced to an effective diameter of 12 inches, and 12 to 9 inches.

Nine hundred and four cement-lined gates are used.

The number of service-pipes is about 6,500, and average consumption 5,000,000 gallons per day.

The first cost of the works was $357,000. The cost to date is not known. Cost of maintenance and repairs for 1879, not including interest, was about $35,000. The hydrants used are made by Bigelow, of New Haven, and about 700 are in use.

Appended will be found a statement of original costs relating to construction in 1862:

Approximate estimate of work done and materials delivered, up to and including December 31, 1862.

Flowage	$6,000 00
Roads	5,000 00
Bridges	20,000 00
Dam	46,840 00
Pump-house	9,959 10
Wheels and pumps	18,000 00
Reservoir	45,160 00
Distribution	119,975 00
Total	270,934 10
Less 10 per cent. reserved	27,093 41
Total	243,840 69
Lands, water-rights, etc	75,000 00
Total amount of estimate	318,840 69

Brought forward		$318,840 69
Work remaining to be done to complete the contract:		
Dam	$3,160 00	
Pump-house	40 90	
Reservoir	840 00	
Distribution	25 00	
		4,065 90
Total		322,906 59
Add reserve percentage		27,093 41
Total		350,000 00
Paid engineer account		7,000 00
Total		357,000 00

Five analyses of the water of lake Whitney give the following results:

Constituents.	ANALYSIS.				
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Organic matter, grains per gallon	1.0	0.0	1.9	8.0	7.0
Inorganic matter, grains per gallon	4.3	3.6	3.7	3.2	3.3

The present engineer is D. Goffe Phipps, esq.

SALEM, MASSACHUSETTS.

Salem contains a population of 27,563. Located on a sandy strip of land between the North and South rivers, two inlets from the Atlantic ocean, it is quite level, with streets laid out at right angles. Its interests are maritime and manufacturing.

The city was one of the earliest in this country to utilize a general water-supply. This water-supply was introduced in 1797 by a number of private citizens, and was brought in 3-inch pipes made of saplings, the head being but a few feet, and the reservoir from which they started consisting of a large cask sunk in the edge of a small pond.

From 1797 the works continued to enlarge and extend under the proprietorship of corporations until January, 1866, when the city began the construction of water-works of much greater capacity. The cost of the old works had reached the sum of over $250,000.

The system as now existing is pumping to a distributing reservoir or to a stand-pipe at will, the water being obtained from Wenham lake, 4½ miles from the city. This lake is situated partly in the town of Beverly and partly in the town of Wenham, with an area of 320 acres and average depth of 53 feet. Its elevation is 31 feet above high tide, and yields an estimated minimum of 2,000,000 gallons per day. It is supposed to derive its water from springs in its bed of sand. Its water-shed is 1,716 acres. A swamp, known as Wenham swamp, a short distance to the northwest, is separated from it by a porous strata, and, owing to an elevation above the lake of a few feet, may furnish much of the supply. The storage supply is practically unlimited.

The water is drawn from the southerly end of the lake by means of a cast-iron pipe 36 inches in diameter and 175 feet long. Its open end projects 32 feet into the lake, and the other enters a stone gate-chamber 10 by 8 feet by 13 feet deep beneath the engine-house.

The well-chamber is divided by a vertical wall of masonry, with four gates, each 2 by 3 feet, one above the other, and regulated by a set of hoisting machinery. Double screens of ⅛-inch mesh copper wire are also used in the chamber opposite these openings. The lake end of the pipe is bell-mouthed and slightly turned upward (with a grating) to facilitate inspection from above. Leaving the well-chamber, the water passes through a brick conduit 26 feet long by 7 feet wide into the pump-well. The latter, as described in the report of the commissioners for 1869, is of masonry lined with brick, 1 foot thick, and 31 feet long by 16 feet wide by 14 feet deep. The bottom is built upon quicksand, and consists of a paving of brick laid upon a flooring or foundation of 2 feet of concrete resting upon a platform of timber. The capacity of the pump-well and brick conduit is 45,000 gallons.

The rainfall at the pumping station was 60.94 inches in 1878, and 39.69 inches in 1879, an average of 50.315 inches for each of the years named.

The engine-house is a plain brick building, 87 by 57 feet by 27 feet high. The engine-room is 53 by 50 feet by 21 feet high, and the boiler-room is 53 by 33 feet by 25 feet high, containing two Worthington duplex compound pumping-engines of 5,000,000 gallons capacity each in 24 hours. The diameter of suction-pipe is 24 inches; of water-piston, 22 inches; the stroke is 48 inches; diameter of low-pressure steam-cylinders, 36⅜ inches; of high-pressure, 21 inches.

Each pump-cylinder contains 64 rubber valves, each 8 inches in diameter. The average speed is 48 strokes per minute. The pumps are run a month at a time, alternately, during about 11 hours per day, five days in the week.

The water is forced through 5,600 feet of 30-inch cast-iron main, under a pressure of 114 feet head, into the distributing reservoir on Chipman's hill, in the town of Beverly. The thickness of the pipe varies from 1¼ inch at

the pumps to $\frac{3}{4}$ inch at the reservoir. The space occupied by each pumping-engine on the floor-line is 30 by $9\frac{1}{2}$ by $9\frac{1}{2}$ feet. The ratio of expansion of the steam in the compound-cylinders is as 3 to 1.

The air-pumps, four to each engine, are each 14 inches stroke and 2 feet diameter; the jet-condensers, 24 inches diameter by 4 feet. A battery of two multitubular boilers furnishes the necessary steam. They are each horizontal, 13 feet long by 63 inches diameter of shell, with eighty 3-inch tubes in each. A new battery, just completed, contains two boilers, each 66 inches diameter by 14 feet long, with ninety 3-inch tubes in each. The evaporative power of the old battery is $9\frac{1}{2}$ pounds of water to 1 pound of anthracite coal; of the new, $10\frac{1}{2}$ pounds of water to 1 pound of coal. The record of these engines for 1879 may be seen from the appended statement from the last report.

The actual duty of the engines is 55,000,000 foot-pounds, and 75,000,000 have been obtained. The guaranteed duty was 60,000,000 foot-pounds.

Time of pumping, hours	2,918.9
Coal consumed, pounds	1,286,270
Water raised to reservoir, gallons	707,552,450

The reservoir, situated on Chipman's hill, is an earthwork 400 feet square and 23 feet deep, and contains 20,000,000 gallons. The elevation of the top surface is 145 feet above high tide. The width of the top of the banks is 15 feet. The interior and exterior slopes are $1\frac{1}{2}$ to 1. A wall of puddle is built through the center of the banks for their entire length, and for a height of $12\frac{1}{2}$ feet above the reservoir bottom it is 10 feet thick, with a thickness of 5 feet for the rest of its height. These puddle-walls are connected with a layer of puddle under the whole bottom of the reservoir from 2 to 4 feet thick. Upon this bottom layer is a bed of gravel, 1 foot thick, upon which a cobble paving of stone is laid. Around the inlet-pipe this paving becomes cement masonry, to prevent damage by the inflow of the water, and is about 50 feet square. The face of the banks is covered with 1 foot of gravel and 15 inches of quarried granite, except at the inlet, where 9 inches of concrete replaces the gravel, and the whole paving is laid in cement. The two effluent-pipes from the reservoir are of 20 inches diameter, one from each of the corners on the south side, and join, a short distance beyond, into one 20-inch main supply-pipe to the city. They take the water from screen-boxes, with copper $\frac{1}{8}$-inch mesh-wire screens, at a point 2 feet from the bottom of the reservoir. Brick piers support these pipes as well as a 12-inch iron waste-pipe, as they pass through the banks.

The force- and supply-mains, on opposite sides of the reservoirs are directly connected by a branch pipe, 30 inches in diameter, passing outside the foot of the western bank; and at a point 510 feet from where it joins the supply-main a small stand-pipe has been erected. The latter is of wrought iron, 30 inches diameter, from $\frac{5}{16}$ to $\frac{1}{4}$ inch thick, and 55 feet high, the top being 25 feet higher than the reservoir. In this arrangement the water may be supplied direct to the city around the reservoir.

The main supply-pipe is 20 inches in diameter, 21,453 feet long, and of cast iron. Where it crosses the river it takes the form of an inverted siphon for a distance of 53 feet, and extends below low water to a depth of $14\frac{1}{2}$ feet. The siphon is 30 inches in diameter.

The distribution is carried out in wrought-iron cement-lined pipes, 12, 10, 8, 6, and 4 inches, respectively, in diameter, the total length of the system being 86 miles, 43 of which are in the town of Beverly.

There are in use (1880) 343 fire-hydrants of the Lowry make, and about 480 Coffin patent gates, made by the Boston Machine Company.

The total consumption averages from 2,000,000 to 2,500,000 gallons per 24 hours, with 4,550 service-pipes or connections.

The first cost of the works may be seen from the accompanying list:

	Actual cost.		Actual cost.
Pumping-engine	$35,117 75	Siphon and bridge	$33,881 00
Engine-house	103,243 29	Contingencies and engineering, 5 per cent	55,805 78
Mains and stand-pipe	321,278 59		
Distribution pipes	253,607 97	Total	930,586 66
Reservoir	127,652 28		

The total cost to December 1, 1879, was $1,388,155, and the annual cost of maintenance for 1879 was $21,114, exclusive of interest.

The following meters are in use:

Kind of meters.	3-inch.	2-inch.	$1\frac{1}{2}$-inch.	1-inch.	$\frac{3}{4}$-inch.	$\frac{5}{8}$-inch.	$\frac{1}{2}$-inch.	Total.
Worthington	....	2	4	51	....	15	....	72
Union rotary	...	1	2	4	4	16	....	27
Ball & Fitts	....	....	....	1	....	1	..	2
Gem	1	....	....	5	....	....	....	6
Crown	....	....	....	....	....	....	1	1
Weir's motor	....	....	....	7	....	....	....	7
Indicators	....	....	....	2	....	....	....	2
Total	1	3	6	70	4	32	1	117

An analysis of the water of Wenham lake, by Dr. Jackson, February 17, 1864, shows that one imperial gallon of this water, equal to 10 pounds avoirdupois, yields:

	Grains.
Organic (vegetable) matter	1.12
Chloride of sodium (sea-salt)	0.40
Sulphate of lime	0.38
Oxide (originally crenate) of iron	0.20
Insoluble siliceous matter	0.12
Total impurity	2.22

The present superintendent is James W. Lyon, esq.

CINCINNATI, OHIO.

Cincinnati contains a population of 255,139, and is situated on the northern bank of the Ohio river, 501 miles above its mouth. Its interests are commercial and manufacturing. The site of the city is a semi-circular basin, rising in two distinct terraces 50 and 108 feet, respectively, above the river, and bordered on the east, north, and west by bluffs 400 feet high, of limestone, belonging to the Hudson River epoch of the Trenton period in the Lower Silurian. The streets are very regular.

In 1826 a supply of water, introduced into the city by a private company, was pumped from the Ohio river. In 1839 the works were purchased by the city, and are now managed by a board of city commissioners. The water is taken from the river at a point nearly opposite the center of the city, about 5 miles below its upper limit, through inlets of masonry and iron pipe. A kind of wall is constructed near the river channel, and forms the face in which the mouths of the inlets are situated. These inlets consist of two stone aqueducts, one 10 feet wide by 21 feet, and 134 feet long from the south end of the pump-house. On the river-end a further extension is made by two 40-inch pipes, resting on the river-bed and extending to the channel. The other aqueduct or conduit is 20 feet wide by 19 feet, and 134 feet long, as before, with a 60-inch iron pipe on the inside, extending a few feet in front of the conduit mouth for an independent supply to pumping-engine No. 6. This, however, has fallen into disuse, the river deposit having completely stopped it up. All these conduits are cleaned out once a year.

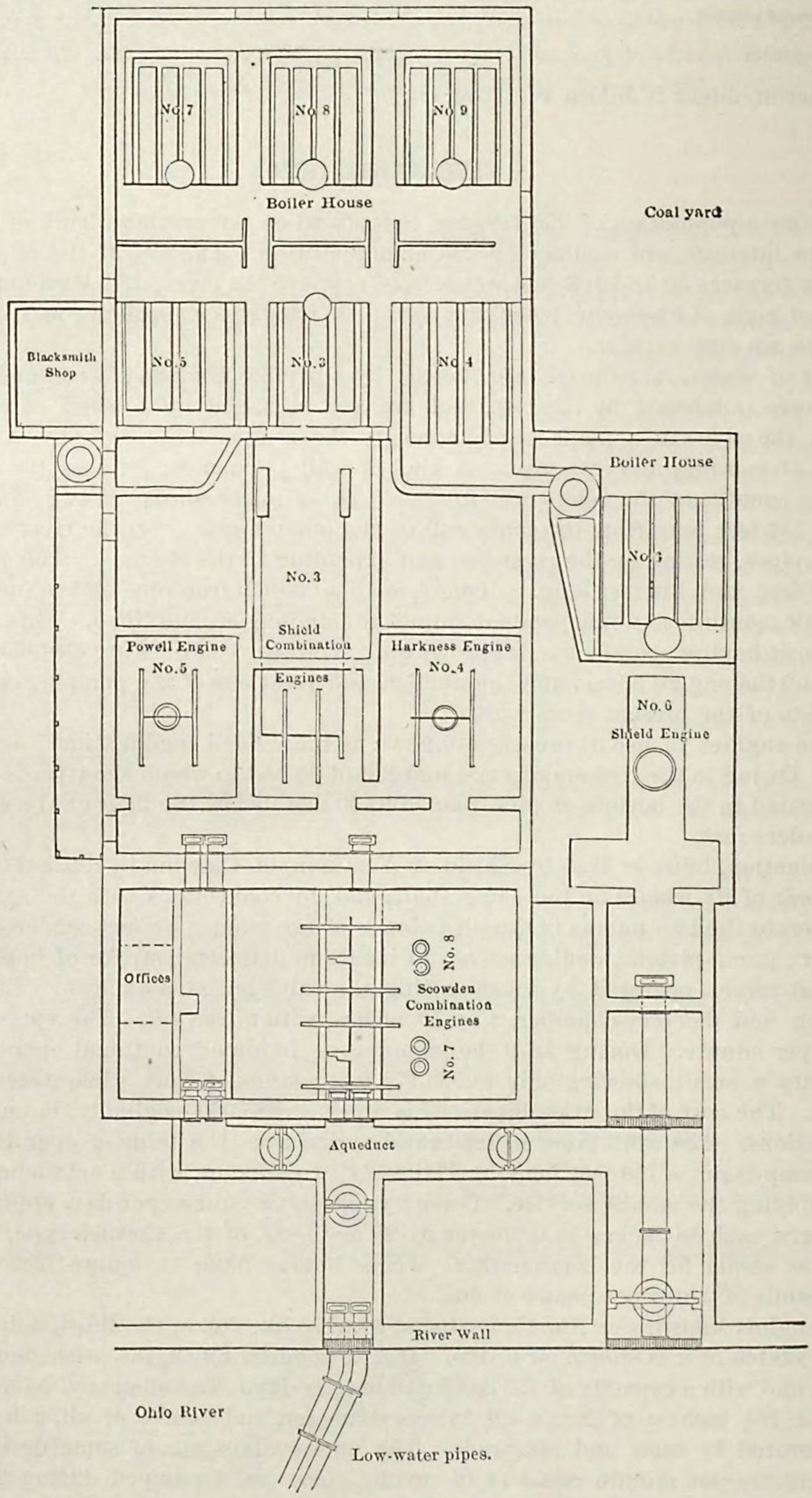
The dimensions of the engine-house, and the number and locations of the pumping-engines, may be seen from the accompanying plan of the present main works.

The oldest of the engines in use at present is known as the "No. 3 combination", a sketch of which is shown in the cut on p. 103. Owing to the tremendous rise and fall of 60 feet to which the river is liable, the pumps of each set of engines are located in the bottom of pits from 50 to 60 feet below the floor of the engine-house, upon which their respective cylinders rest.

The No. 3 combination, built in 1845 by Shield & Yeatman, of Cincinnati, consists of two horizontal steam-cylinders driving a pair of fly-wheels on the same shaft, and, by connections with the same crank-pins, vertically acting pump-rods operate the two pumps in the pit below. These pumps are non-condensing, with steam-cylinders 23 inches in diameter; pump-pistons, double-acting, 14 inches in diameter; stroke of both, 10 feet. The steam is distributed by puppet-valves, operated by a cam lifting the valve-levers, as shown. There are two brass hinge-valves in each suction- and delivery-chamber, 8 by 10 inches, with a free lift. The speed of the engine averages 12 or 14 revolutions per minute. During 1879 the pumps were in almost continual operation 24 hours per day for 241½ days. Their duty is small, showing only 43,566,178 foot-pounds of work when tested in 1872, although given at 48,000,000 in 1880. The cost of the "Combination" is given at $85,000 originally, but much has since been spent in repairs and alterations. The work done in 1880 can be seen from the table of operation for all engines, given on page 104. The pump-main is 750 feet long by 17 inches in diameter, with a maximum pressure on the pumps of 224 feet when supplying the middle service. Capacity, 5,000,000 gallons per day, approximately. A battery of three horizontal boilers, each 48 inches in diameter by 26 feet long, of the Cornish type, with eight flues 8 inches in diameter, furnishes steam for the combination. These boilers have 44 square feet of grate-surface and an evaporation of 8½ pounds of water per pound of coal.

As the second engine, known as "No. 4", is almost exactly like No. 5, the third, a description of the one will answer for both. A sketch of it is shown on p. 105. It is a condensing-engine, with double-acting piston-pumps, the same as in No. 3, and with a capacity of 4,500,000 gallons per day. The steam-cylinder is 45 inches in diameter. Pump-piston of No. 4, 18½ inches; of No. 5, 19⅛ inches diameter, and stroke of all, 8 feet. Double-beat puppet steam-valves are operated by cams and plug-rods. The pump-valves are of same design and size as in No. 3. Average speed of engines per minute equal to 16 revolutions. No. 4 pumped during 320$\frac{3}{10}$ days of 24 hours in 1879, and 262¾ days in 1880, through 750 feet of 20 inch force-main against a static head of 165 feet. The jet-condenser connected with it is 4 by 4 feet, with an air-pump 3 feet diameter by 3 feet stroke. The duty-trial made at same time as last showed 37,789,990 foot-pounds, and in 1880, 38,014,283 foot-pounds. The two engines, Nos. 4 and 5, are used only for the low-service. The cost of the former was $30,000, and it was built by Harkness & Son, of Cincinnati, in 1850; the latter by Powell & Son, of Cincinnati, in 1854, for $35,000, and both after designs

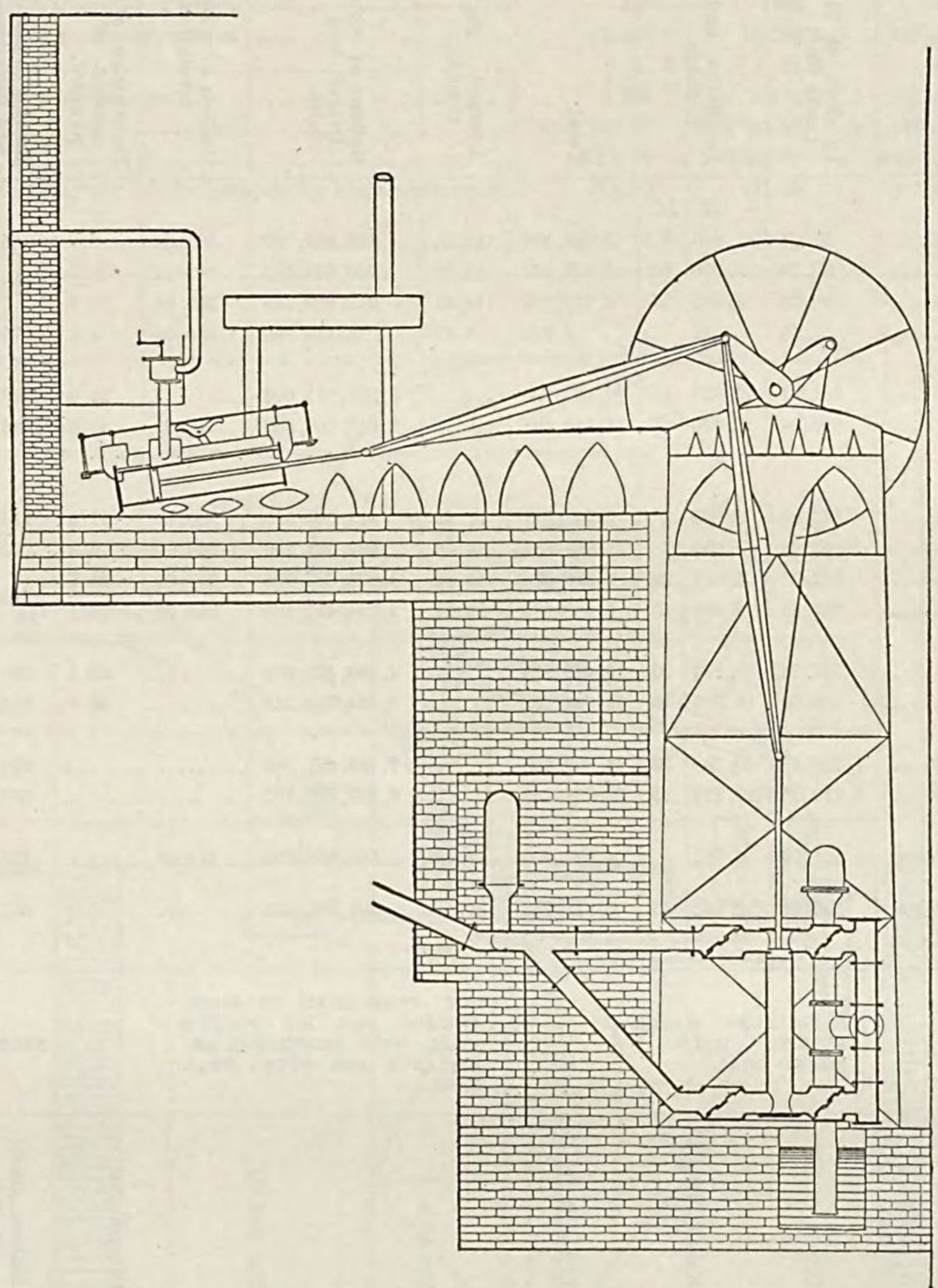
by T. R. Scowden, C. E. Two batteries of 4 boilers each, and similar to those last described, furnish steam for the two engines, No. 4 being 30 feet long by 72 inches diameter, with three flues 17 inches, and two 21 inches diameter, and No. 5 battery being 30 feet long by 54 inches diameter, with eight 8-inch flues and external furnaces. Those for No. 4 have grate-surface of 133 square feet and evaporation of 8 to 1,and for No. 5 grate-surface of 64½ square feet, evaporating 8½ pounds of water to 1 pound of coal.



PLAN OF MAIN PUMPING-WORKS.

Engine No. 6, which is used as auxiliary to the others in the works, was built in 1865 by the water-works, after designs by George Shield, at a cost of $200,000, and is of theoretical capacity of 20,000,000 gallons, but actual available capacity of only 12,000,000 gallons per day. It is a condensing vertical-acting Bull-pump, the pump-cylinder being directly beneath and the plunger operated by an extension of the piston-rod. The steam-cylinder

is 100 inches in diameter and the stroke 12 feet. The steam-valves are balanced puppet, with buffet on the plug-rods. The condenser is of jet pattern, 6 feet diameter by 3½ feet deep, with an air-pump 32 inches diameter by 12 feet stroke, located immediately beneath the steam-cylinder, and having its piston operated by the rod of the steam-piston. The vacuum obtained is equivalent to but 14 inches. The duty of the engine averages from 21,500,000 to 29,750,000 foot-pounds, and it is used for both low and middle service against lifts of 179¼ feet and 247$\frac{33}{100}$ feet,



SKETCH OF "NO. 3 COMBINATION" PUMPING-ENGINE.

respectively, including friction. On the trial-test in 1872 the duty developed was 23,580,687 foot-pounds. The water-cylinder contains one double-acting piston-plunger, 46 inches diameter, with 12 feet stroke. There are two valve-chambers at each end of the cylinder, which contain 7 rubber-faced iron puppet-valves each. They are 14 inches diameter, with a lift of 2½ inches. The velocity of the engine averages 12 double strokes per minute when in operation. There is a battery of five boilers, with external furnaces, each boiler being 28 feet long by 72 inches diameter, and containing each five flues—three of 17 inches and two of 21 inches diameter. They have a surface of 133¾ square feet, and evaporation of 10.12 pounds of water per pound of coal supplies the steam to operate it. The coal used is first-quality bituminous for all the boilers in the works.

Engine No. 6 is connected by a 50-inch main 750 feet long, to the old or Third Street reservoir, and also with the Eden Park basin by 3,300 feet of 46-inch main, enabling water to be forced into either by simply operating a valve.

Engines Nos. 7 and 8, duplicates of each other, were built in 1874 by the Cincinnati Engine & Hydraulic Works, after designs by T. R. Scowden, at a cost of $204,000. They are duplex non-condensing engines, with steam-cylinders 28 inches diameter; pump-cylinders, 23½ inches; plungers, 16½ inches by 8 feet stroke, the pumps being of the Thames-Ditton variety. The average speed when in operation is 14 revolutions per minute, and in 1880 they were operated, No. 7 about 283½ and No. 8 about 267 days of 24 hours. The steam double-beat valves are operated by rocking-cams and plug-rods. Their duty averaged in 1880 about 39,000,000 foot-pounds. In the pump-chambers there are 7 receiving and 6 discharge brass puppet-valves, the former being 10 inches and the latter 12½ inches diameter. In the eduction main are 7 check-valves of same dimensions as the receiving valves. The force-mains from the pumps to the reservoir in Eden park is 24 inches diameter by 3,690 feet long. The capacity of the two engines is 15,000,000 gallons per day, pumped into the reservoir against a static head of 220 feet. The steam

is derived from three batteries of four boilers each, with shells 48 inches diameter by 26 feet long, each containing five flues—two of 11 inches, two of 12 inches, and one of 16 inches diameter.

Operation of the Cincinnati pumping-works for the year 1880, *showing the performance of each service and engine.*

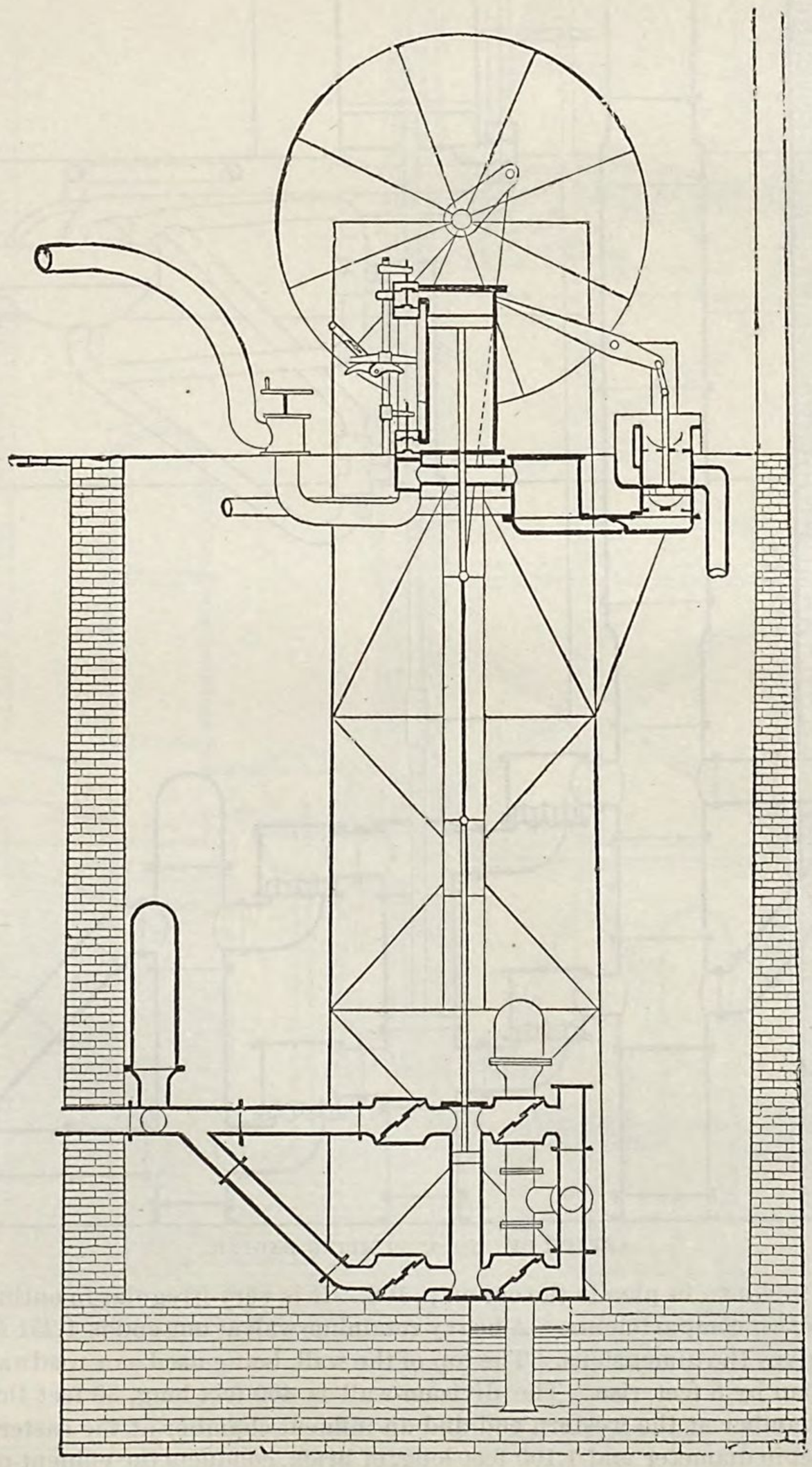
	RUNNING TIME.		REVOLUTIONS MADE.		Gallons of water delivered into reservoirs.	Gallons of water per revolution.	Percentage of total amount of water pumped.	COAL CONSUMPTION.			
	In days of 24 hours each.	In hours and minutes.	Total.	Average per minute.				Raising steam and banking—pounds.	For pumping—pounds.	Total pounds.	Daily average in tons.
Low service:		*H. M.*									
No. 3, Combination engine	37.71	905 5	662,899	12.21	198,869,700	300.00	2.7	68,913	710,628	779,541	.....
No. 4, Harkness engine	262.79	6,306 50	5,925,002	15.66	1,203,863,575	203.18	16.5	} 126,412	7,837,736	7,964,148	.....
No. 5, Powell engine	200.25	4,805 35	4,273,735	14.82	919,009,185	215.04	12.6				
No. 6, Shield engine	0.46	11	2,294	3.47	4,129,200	1,800.00	0.1	15,078	13,414	28,492	.....
Total for Front street, 1880	501.21	12,028 30	10,863,930	.....	2,325,871,660	.....	31.9	210,403	8,561,778	8,772,181	12.00
Total for Front street, 1879	525.96	12,826 20	11,140,491	.....	2,612,706,830	.....	40.6	348,425	9,924,224	10,272,649	14.07
Middle service:											
No. 3, Combination engine	162.88	3,909 5	2,742,331	11.69	823,060,520	300.13	11.3	116,612	3,617,291	3,733,903	.....
No. 6, Shield engine	43.92	1,054 5	281,834	4.46	507,301,200	1,800.00	7.0	50,935	3,453,919	3,504,854	.....
No. 7, Scowden engine	283.63	6,807 25	5,376,688	13.16	1,874,687,055	348.66	25.7	} 246,932	18,789,624	19,036,556	.....
No. 8, Scowden engine	266.83	6,404 15	5,038,570	13.11	1,754,451,160	348.20	24.1				
Total for Garden of Eden, 1880	757.26	18,174 50	13,439,423	.....	4,959,499,935	.....	68.1	414,479	25,860,834	26,275,313	35.90
Total for Garden of Eden, 1879	633.59	15,206 15	11,694,292	.....	3,844,990,342	.....	59.4	319,486	18,351,935	18,671,421	25.58
Total for both (main works), 1880	1,258.47	30,203 20	24,303,353	.....	7,285,371,595	.....	.....	624,882	34,422,612	35,047,494	47.90
Total for both (main works), 1879	1,159.55	27,832 35	22,834,783	.....	6,457,697,172	.....	.....	667,911	28,276,159	28,944,070	39.65
Total Mount Auburn high service, No. 1 old power, 1880.	196.79	4,723	4,022,020	14.19	563,082,800	140.00	.....	378,000	2,620,588	2,998,588	4.10
Total Mount Auburn high service, 1879.	230.64	5,562 45	6,812,732	.....	597,796,271	.....	.....	393,000	3,090,710	3,483,710	4.77

	NO. GALLONS WATER PUMPED WITH 1 POUND COAL.		Lift with friction, in feet.	DUTY PERFORMED IN FOOT-POUNDS PER 100 POUNDS COAL, WITH FRICTIONAL RESISTANCE AND TOTAL COAL USED.		STORES USED.				LUBRICANTS.	
	Into reservoir.	Raised 100 feet high.		For 1879.	For 1880. (*a*)	Oil, gallons.	Tallow, grease, pounds.	Cotton waste, pounds.	Packing, pounds.	Cost.	Cost per 1,000,000 gallons.
Low service:											
No. 3, Combination engine	255.11	446.01	174.83	42,474,029	37,197,321	21	23	42	19¼	$24 71	$12 42
No. 4, Harkness engine	} 266.55	455.80	171.00	39,218,632	38,014,283	32½	57	95	67½	41 45	3 44
No. 5, Powell engine						33½	49½	95	82	41 55	4 52
No. 6, Shield engine	144.92	259.77	179.25	26,251,775	21,665,474	1¾	.....	6	14	1 58	39 50
Total for Front street, 1880	265.14	453.39	171.00	.....	.....	88¾	129½	238	182¾	109 29	4 70
Total for Front street, 1879	254.33	453.80	174.50	.....	.....	114¼	98	246½	110½	137 50	5 26
Middle service:											
No. 3, Combination engine	220.43	531.24	241.00	45,417,212	44,304,907	88¾	78½	107	77	95 91	11 65
No. 6, Shield engine	144.74	357.99	247.33	.....	29,856,494	32¾	15	30	125	32 00	6 37
No. 7, Scowden engine	} 190.64	467.07	245.00	40,744,354	38,953,517	231¾	83	200	45½	200 26	10 68
No. 8, Scowden engine						221¼	103½	187½	148⅝	194 49	11 08
Total for Garden of Eden, 1880	188.76	462.46	245.00	.....	.....	574½	280	524½	396⅛	522 96	10 54
Total for Garden of Eden, 1879	205.93	509.32	247.33	.....	.....	454½	227¾	623	350¼	466 80	12 14
Total for both (main works), 1880	207.87	463.55	223.00	.....	.....	663¼	409½	702½	579	602 25	8 68
Total for both (main works), 1879	223.11	496.60	218.10	.....	.....	568¾	325¾	869½	460¾	604 30	9 37
Total Mount Auburn high service, No. 1 old power, 1880.	187.78	550.20	293.00	41,312,709	45,886,944	48¾	.....	188	207	36 30	6 43
Total Mount Auburn high service, 1879.	171.62	502.84	293.00	.....	.....	57	.....	171½	167½	42 10	7 04

a Inferior coal used during part of year.

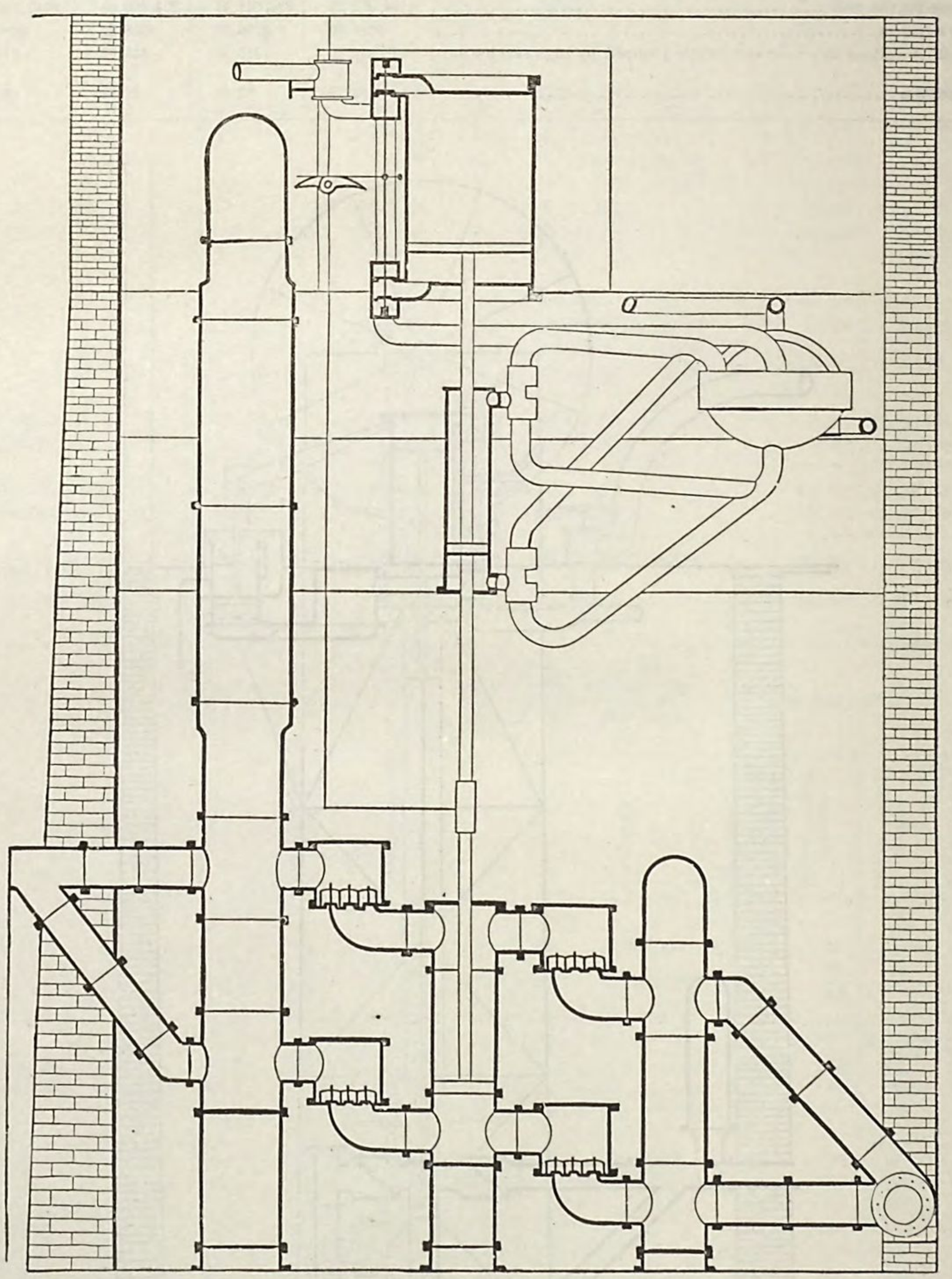
Grand total of all the services.

Services.	1876.	1877.	1878.	1879.	1880.
Water pumped from river (low and middle services), in million gallons	6,321	6,005	6,274	6,457	7,285
Water pumped by high service, second lift, in million gallons	529	592	599	598	563
Coal consumed during the year for pumping purposes, in tons	18,495	16,395	16,306	16,213	19,023
Daily average consumption of coal, in tons	50.9	44.9	44.7	44.3	51.97
Pounds of coal for each million gallons of water pumped	5,399	4,970	4,745	4,597	4,848
Current pumping expense for the year	$104,972 25	$93,641 44	$94,496 88	$102,505 59	$114,923 32
Daily average pumping expense	$286 80	$256 55	$258 39	$280 84	$314 00
Cost of pumping one million gallons into reservoir (water pumped by high service not considered).	$16 60	$15 59	$15 06	$15 88	$15 77
Average price of coal per ton	$2 77	$2 38	$2 43½	$2.58½	$2 86



SKETCH OF "NO. 4" PUMPING-ENGINE.

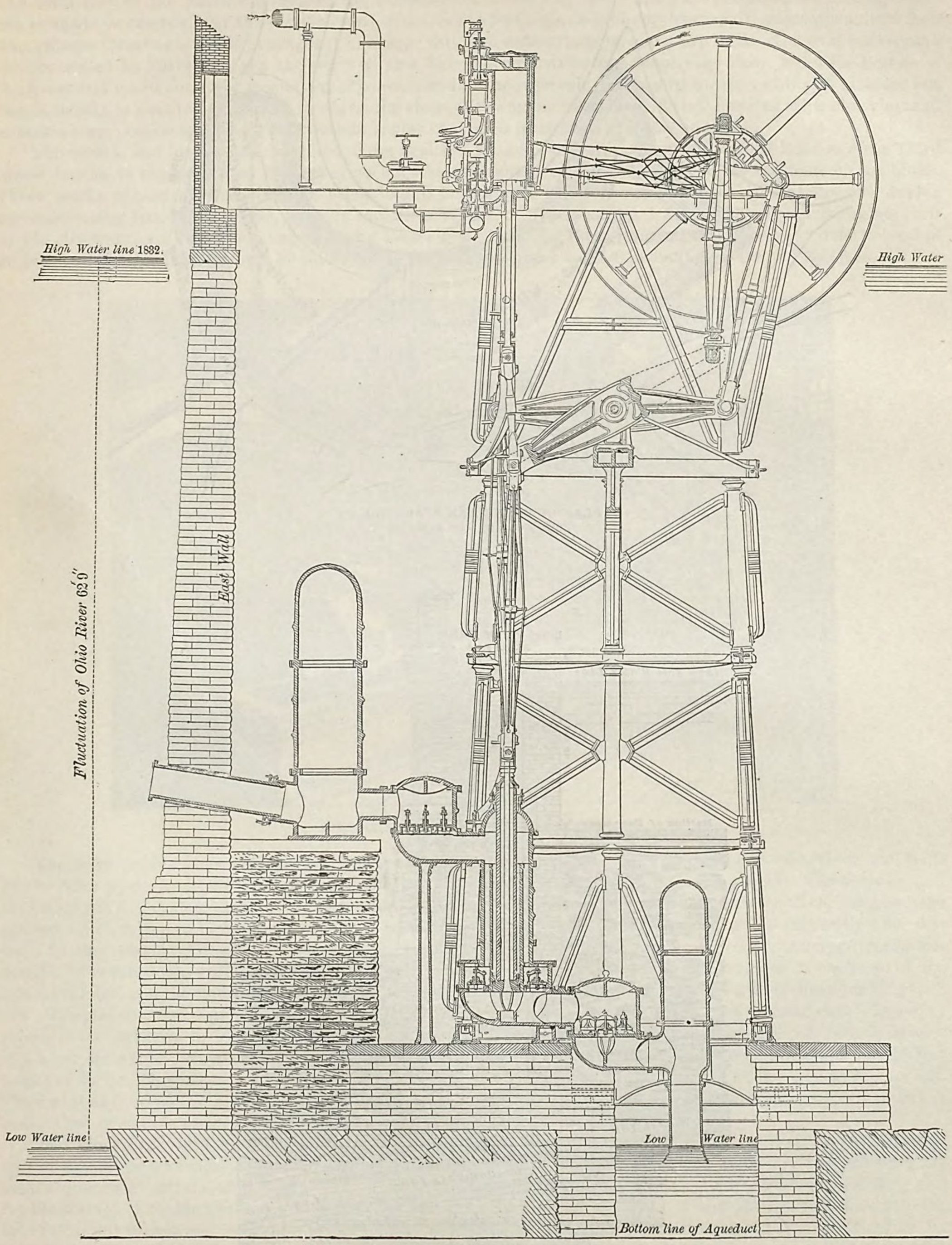
There are in use two reservoirs, one of which is known as the old Third Street and the other as the Eden Park basin. The former is rectangular in plan, divided by a wall into two compartments. One of the latter is at the bottom, 172½ by 108½ feet, and the other 158 by 108½ feet, with interior slope of about 1 to 6. The dimensions at level of banks are, respectively, 180¾ by 116¾ and 163½ by 116¾ feet. The capacity of the former, at 22 feet depth, is 3,249,628 gallons, and of the latter, 2,961,024 gallons. Total depth, 24 feet. The reservoir is at an altitude of 165 feet above the pumping-works, and is entirely above level. The walls have a hollow space between them, and are 7½ feet thick at top by 10 feet at base, and are tied together at intervals. This basin serves for the low service, and is the recipient of water pumped by engines Nos. 3, 4, 5, and 6.



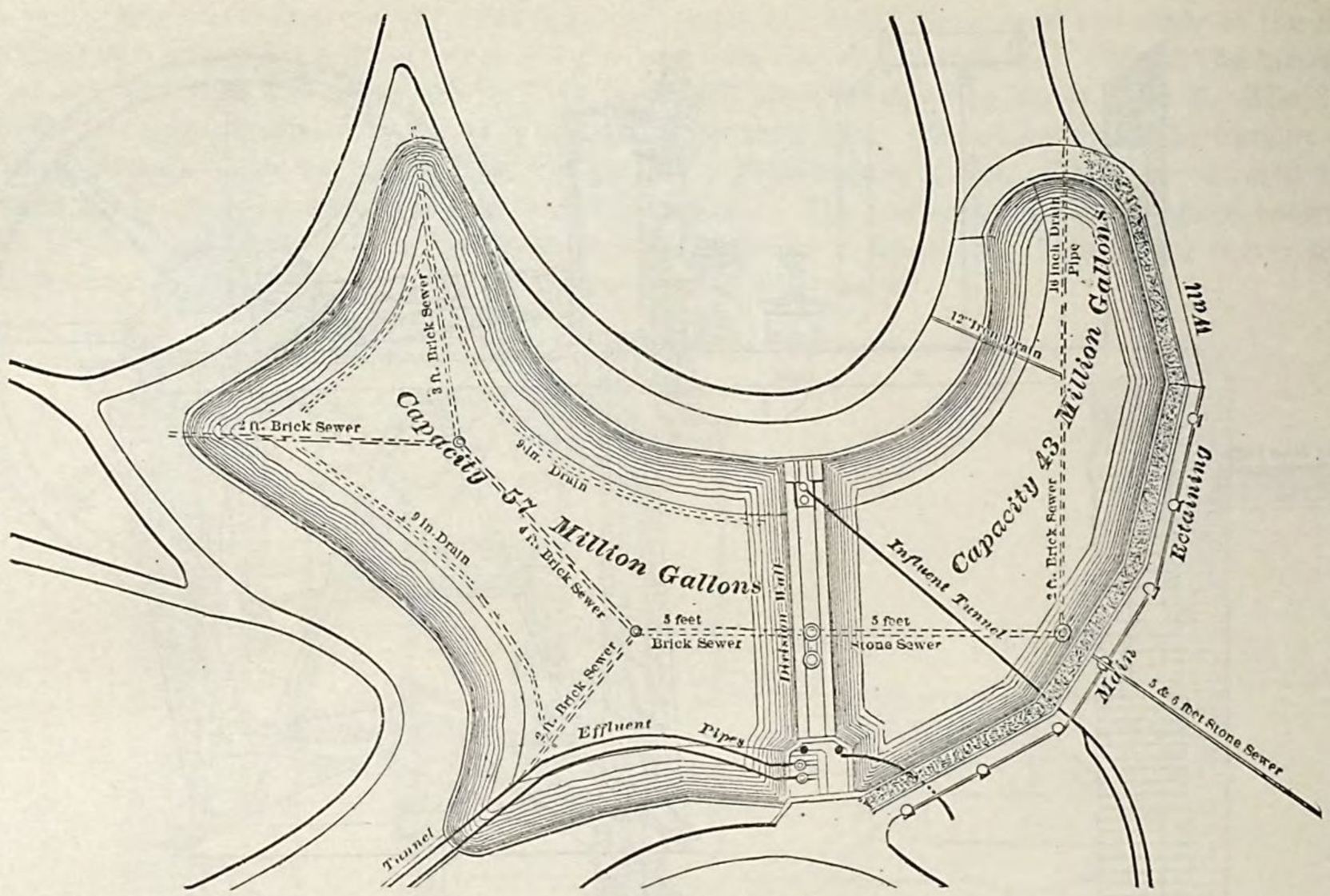
SKETCH OF "NO. 6" PUMPING-ENGINE.

The Eden Park basin is shown in plan in the cut on p. 108. It is very irregular in outline, and is separated by a masonry division-wall into two compartments. A heavy retaining-wall at one end is 1,251 feet long, and is shown in section in the cut, which gives the dimensions. The top of the wall, being used as a roadway, is supported by eight elliptical arches, 55 feet span by 8 feet rise. The division-wall is 400 feet long, 30 feet thick at base by 10 feet at top, and has an effluent-chamber at the western end and an influent-chamber at the eastern end. A tunnel under the hill to the north, 12 feet in diameter and 1,100 feet long, of brick, conducts the effluent-pipes to the supply-pipes.

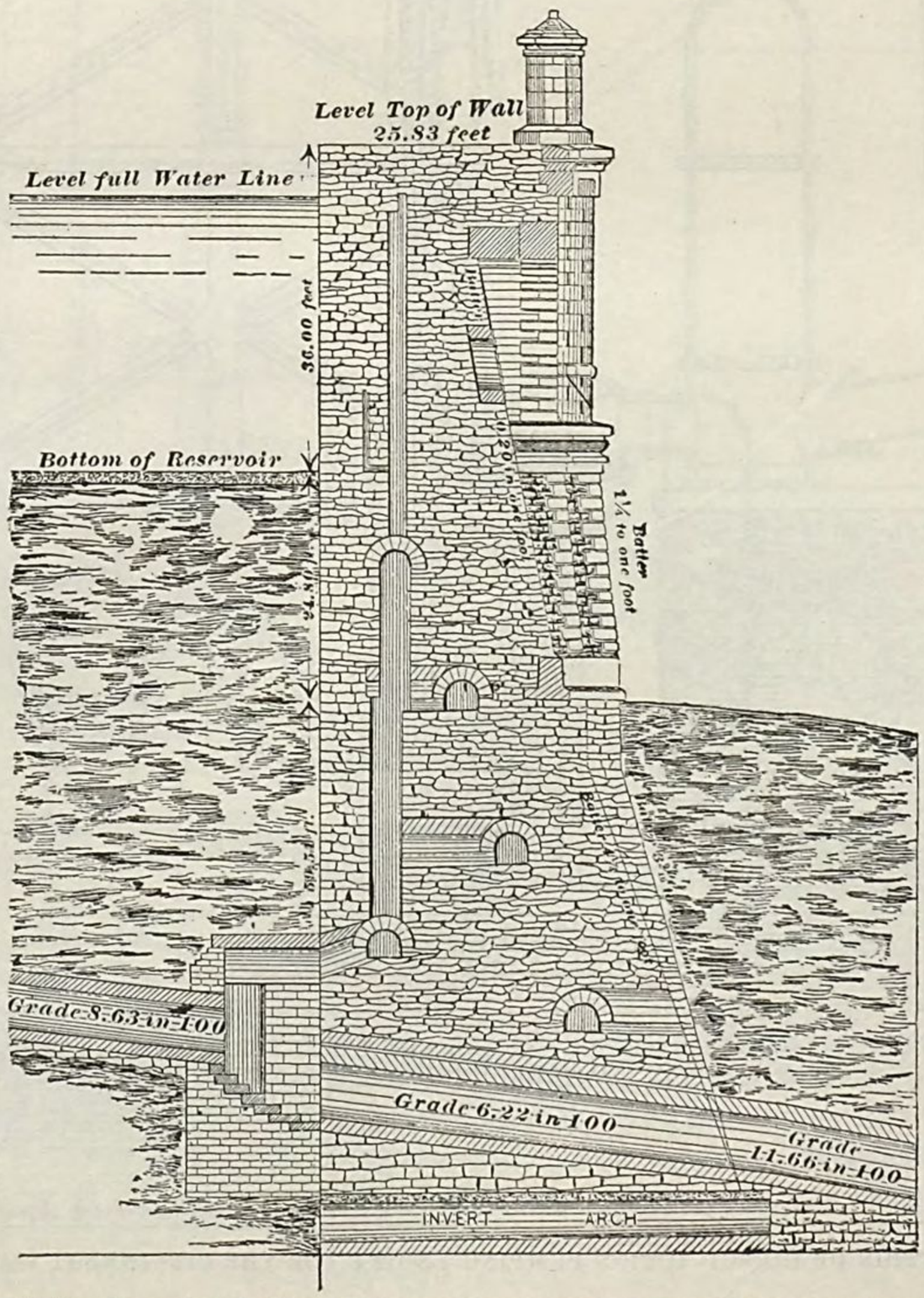
The depth of water in front of the main retaining-wall is usually only about 29 feet. Total area of high-water surface is 7 acres, and capacity 100,000,000 gallons. The division- and retaining-wall are both of rubble masonry.



VERTICAL SECTION OF DIRECT-ACTION PUMPING-ENGINE FOR THE CINCINNATI WATER-WORKS.



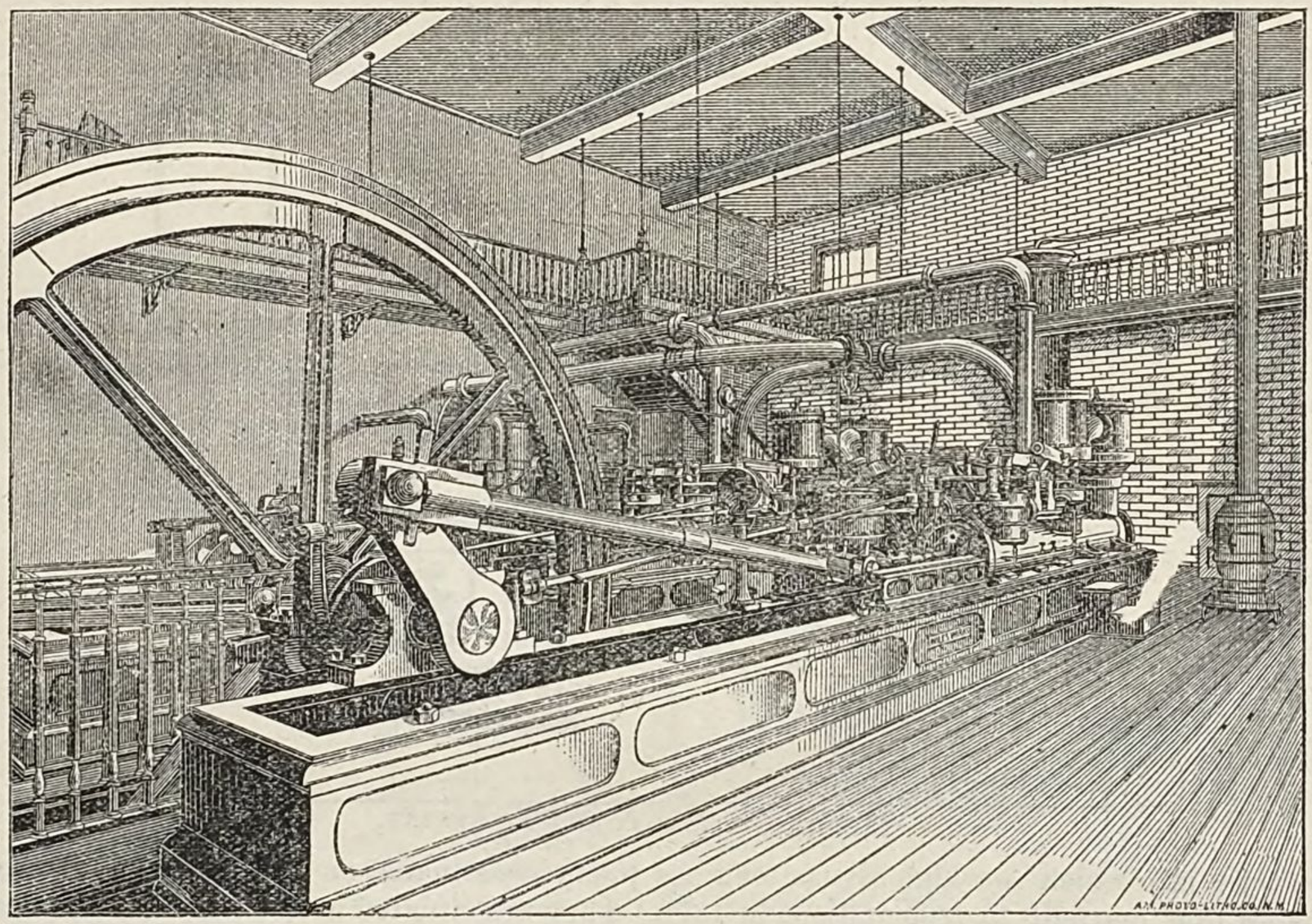
PLAN OF EDEN PARK RESERVOIR.
Built, 1866–1876; cost, $1,660,000.



SECTION OF MAIN RETAINING WALL, GARDEN OF EDEN RESERVOIR.

The total cost of the basin was $1,660,000, $1,000,000 of which was spent upon the retaining-wall. The water can be made to cascade over the division-wall, which is 67½ feet high, but the depth is usually maintained at 29 feet. The effluent-chamber is made pentagonal in shape, with two compartments, one a dry well. The oval water-ways are controlled by valves. From the wet well two 35-inch iron distributing mains pass along under the bottom of the lower basin and enter the tunnel already mentioned. The reservoir, being surrounded by hills on all sides but one, is mostly in excavation around its sides, the slope of the upper basin being 2 to 1, puddled with blue clay and imbedded with concrete. The whole bottom is also concreted from 12 to 18 inches in depth.

The middle and low service, supplied under heads of 172 and 110 feet, respectively, by the Eden and the Third Street basins, is supplemented by high-service works on Hunt street for the supply of the residents on the bluffs. These works consist of a rectangular brick engine-house, with boiler-house attached. It contains one duplex non-condensing horizontal-engine, built by the Niles Works, of Cincinnati, and a vertical compound engine, built by the city water-works. These engines take their supply from the Eden reservoir supply-mains, under a head of 60 feet, and force it into a couple of tanks on mount Auburn, under a head, including friction, of 340 feet.

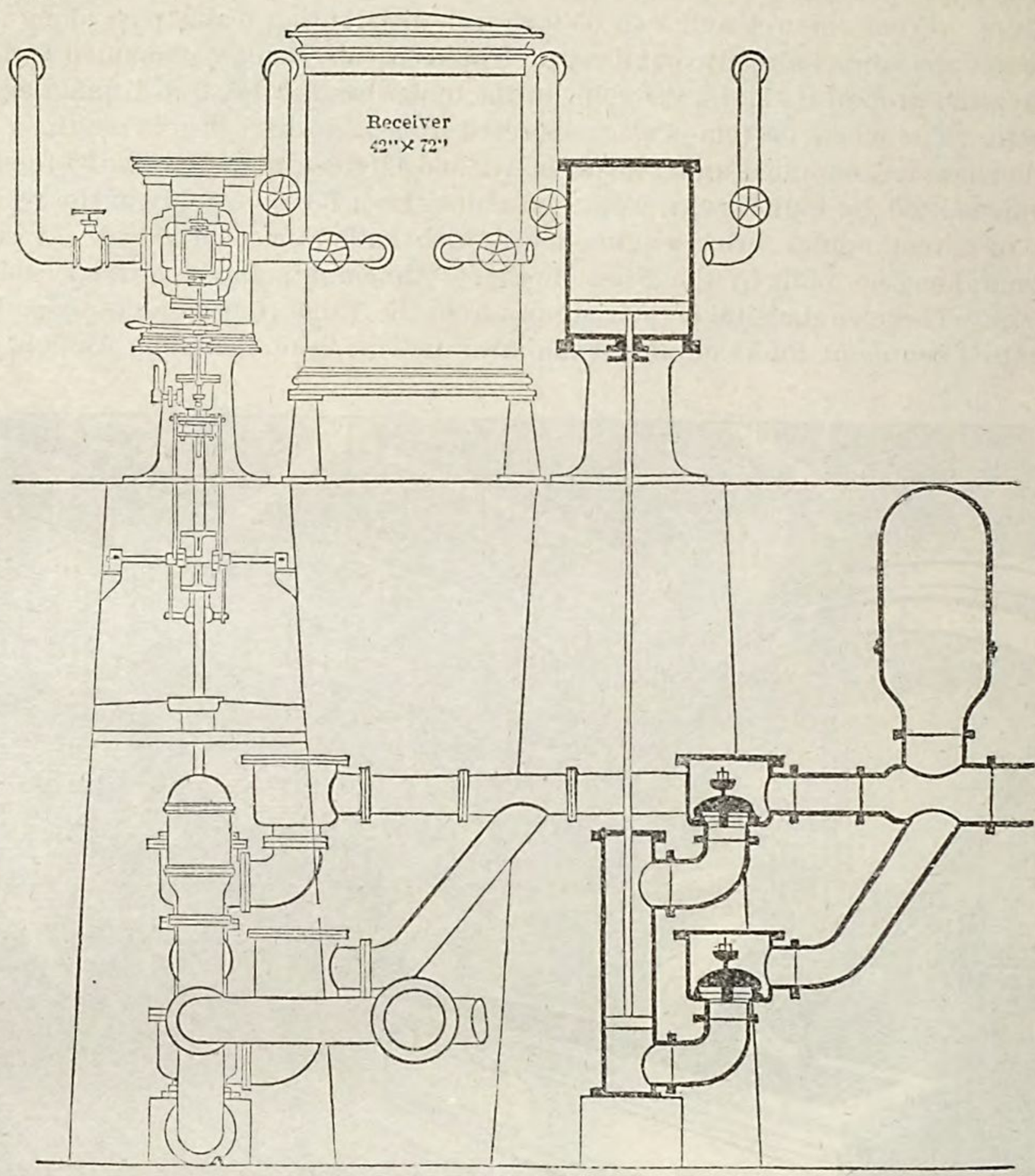


DUPLEX NON-CONDENSING NILES ENGINE.

The Niles engine shown in the cut, was designed by Arthur G. Moore, the present superintendent, and built by the Niles works in 1869. It is non-condensing, with steam-cylinder 18 inches in diameter by 5 feet stroke, and the pump-rod is a prolongation of the piston-rod. The pump-cylinder is 13⅜ inches diameter, and the friction-head against which it pumps is 290 feet, through a main 20 inches diameter for 2,705 feet, and 16 inches by 4,501 feet long, for the remaining distance. The capacity of the pumps is 4,000,000 gallons per day. Average speed per minute, 18 revolutions, working 12 hours per day. There are four inlet- and four outlet-valves at each end of the pump-cylinder, and the pump is double-acting. These valves are brass puppet-valves, 7 inches diameter by ⅝-inch lift. The steam-valves are puppet relief-valves, operated by straight levers raised by a rocking-cam. The duty shown in its operation in 1880, during 196¾ days' running time, was 45,886,944 foot-pounds per 100 pounds of coal of an inferior grade. Steam is derived from two batteries of two boilers each, with 48 inches diameter and 24 feet length of shell. They each contain two 10-inch and four 8-inch flues, and the pressure is maintained at 125 pounds. Their evaporative power with the poor grade of coal in use is given at from 9 to 11 pounds water per 1 pound of coal. Cost of engine erected, $15,000.

The other high-service engine, built by the water-works, after the design of Americus Warden, in 1879, at a cost of $8,600, is a vertical compound engine, with high-pressure cylinder 14 inches diameter; low-pressure, 22½ inches diameter. Stroke of both, 2½ feet. Pump-cylinders, 10 inches diameter; stroke of plunger, 2½ feet, and double-acting. The high-pressure cylinder exhausts into the receiver between it and the low-pressure, and the latter draws it thence and exhausts into a heater for the feed-water. The steam-valves are D-slides operated by the Cope & Maxwell isochronal cataract gear. The cylinders and their pumps connected can be operated at high pressure separately. The pumps have a single suction- and delivery-valve in each end of the cylinder. They are

hemispherical rubber discs on brass seats, with spindle. The area of opening is 40⅔ square inches. The receiver is 42 inches diameter by 72 inches high, with 4-inch connecting pipes. The cylinders derive steam from one of the batteries last described.



WARDEN VERTICAL COMPOUND ENGINE.

The reservoirs into which the high-service engines pump are situated on mount Auburn, and consist of two tanks of wrought iron, one built in 1869 and one in 1871. They are situated at McMillan and Auburn streets, and are each 60 feet diameter by 38 feet deep, with its bottom of ¼-inch plate resting upon a bed of sand. The plates are 50 by 140 inches each, and vary in thickness from $\frac{11}{64}$ to $\frac{7}{16}$ inch. The cost of each was $15,000. The vertical seams are lap-welded and double-riveted. The force-mains supplying these tanks being tapped, they serve merely as stand-pipes to maintain the pressure.

The total length of distribution mains January 1, 1881, was 188.86 miles, of the sizes, etc., shown in the subjoined summary:

	Feet.
3-inch	55,933
4-inch	486,027½
5-inch	2,040
6-inch	133,805
8-inch	47,663
10-inch	145,394
12-inch	193
14-inch	603
16-inch	21,346
20-inch	78,029½
24-inch	5,607
30-inch	582
35-inch	7,337
36-inch	4,783
40-inch	3,782
46-inch	3,294
50-inch	803

Total number feet of cast- and wrought-iron water-pipe of all sizes in use in the city of Cincinnati December 31, 1880, 997,222 feet=188.86 miles, with 2,334 valves.

There were laid in the city up to 1838 about 118,000 feet of 2½-inch bored logs, most of which are discarded, and none laid since that time. Two 35-inch mains from Eden reservoir and two 20-inch pipes from the Third Street basin are all the supply-pipes in use. There are in use 789 hydrants, mostly manufactured by Cummings & Son, of Cincinnati.

There are 23,000 water-takers recorded, and the consumption in 1880 averaged 19,476,000 gallons per day, of which 32 per cent. is supplied to the low, 67 per cent. to the middle, and 1 per cent. to the high service.

The city, in 1839, when it purchased the works, paid $300,000 for them. With the extension of them the total cost to January, 1881, amounted to $6,727,838. The annual cost of maintenance and repair for 1880 amounts to $200,000, and the total revenue for the same period has been $523,100.

Of meters there are in use January 1, 1881, 545, as follows:

Kind of meter.	¼-inch.	⅝-inch.	1-inch.	1½-inch.	2-inch.	3-inch.	4-inch.	Total.
Worthington	....	104	247	61	55	24	8	499
Union	....	28	.....	6	....	....	....	34
Gem	8	.....	.....	....	....	....	....	8
Marsland	....	.....	1	...	....	....	....	1
Ball & Fitts	....	1	.....	....	....	....	....	1
Crown	2	.....	.....	....	....	....	....	2
Total	10	133	248	67	55	24	8	545

In addition to these there are 318 hydraulic elevators.

It is proposed to erect new works on the river, outside of the city limits, at a point farther up, known as Markley's farm, where settling basins are to be used.

Analyses, made by Mr. Stuntz, of the water at different points in the Ohio river and of the works show the following results:

Parts by weight in 100,000 of water. Hardness: Grains of $CaCO_3$ in United States gallons.

Locality.	Date.	Ammonia.		Residues dried at 212° F.			Chlorine.	Hardness.	Temp. deg. F.	
		Free ammonia.	Albuminoid ammonia.	Inorganic solids.	Organic and volatile.	Total solids.			Water.	Air.
	1880.									
Bonte's well, Dayton, Kentucky	September 17	.....	.....	.....	.....	.....	.....	39.1	.....	.....
Bellevue well, Brickyard	September 17	.....	.....	.....	.....	.....	.....	32.5	.....	.....
Pumping-works	September 17	0.0047	0.0218	6.96	2.82	9.78	0.62	6.3	67	74
Eden reservoir	September 17	0.0045	0.0214	11.22	3.16	14.38	0.75	6.8	74	76
Storrs	September 17	0.0132	0.0150	9.16	3.96	13.12	0.70	5.8	64	74
Markley farm	September 18	0.0016	0.0121	8.20	2.94	11.14	0.22	5.3	67	82
Sand beach	September 28	0.0083	0.0099	7.76	2.58	10.34	0.27	7.4	68	71
Sand beach	October 4	0.0099	0.0087	8.96	4.64	13.60	0.22	7.4	68	70
Storrs	October 16	0.0118	0.0236	9.16	3.96	13.12	0.77	5.7	67	74
Sand beach	November 1	0.0054	0.0075	9.32	2.60	11.92	0.25	7.3	56	47
Pumping-works	November 1	0.0050	0.0156	11.14	4.66	15.80	1.33	8.3	50	49
Storrs	November 1	0.0180	0.0198	11.10	2.70	13.80	1.16	8.5	50	49
Eden reservoir	November 1	0.0231	0.0200	11.68	2.18	13.86	0.91	9.2	50	49
Markley farm	November 3	0.0015	0.0024	13.16	2.54	15.70	0.39	8.2	50	59
Sand beach	November 9	0.0040	0.0244	7.82	1.70	9.52	0.30	7.0	56	54
Markley farm	November 9	0.0042	0.0628	12.44	3.32	15.76	0.83	6.0	43	54
Pumping-works	December 3	0.0076	0.1366	11.06	6.80	17.86	0.44	6.8	45	35
Storrs	December 4	0.0262	0.1200	13.84	4.02	17.86	0.34	4.7	36	40
Eden reservoir	December 4	0.0209	0.0728	10.38	3.20	13.58	0.64	7.4	35	39
Markley farm	December 4	0.0080	0.0420	16.38	2.72	19.10	0.43	4.6	35	45
Sand beach	December 14	0.0031	0.0170	11.00	2.38	13.38	0.41	7.9	56	44

The works are now managed by Mr. Arthur G. Moore as superintendent and chief-engineer, appointed by the board of public works.

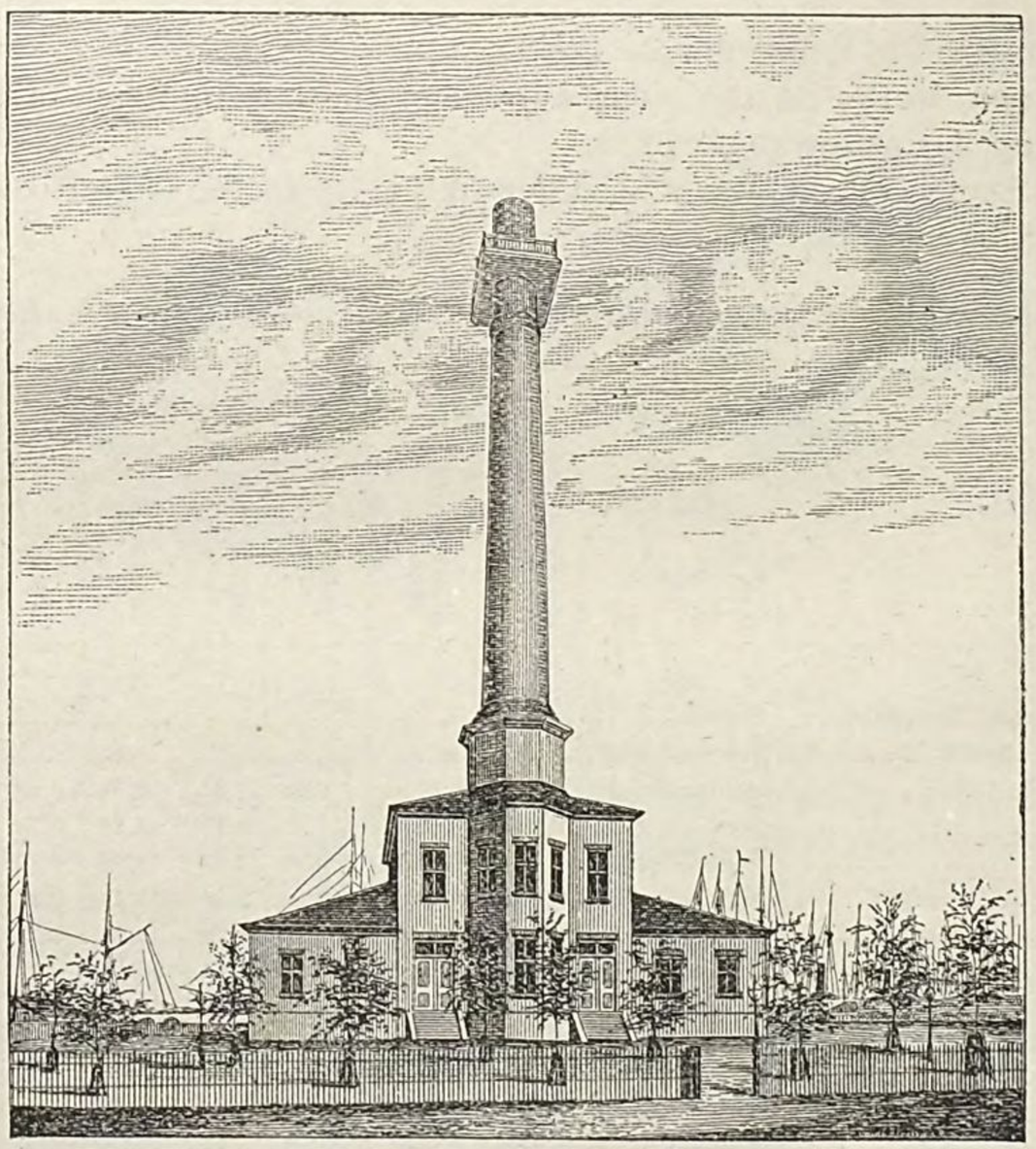
The water is sold under a special tariff of water-rates.

CLEVELAND, OHIO.

Cleveland, with a population of 160,146, and situated on the shores of lake Erie at the mouth of the Cuyahoga river, is an extensive manufacturing city. Its streets intersect each other at right angles, and most of them are on a plain elevated from 80 to 100 feet above the surface of the lake and that of the river, whose banks rise to about the same height on either side.

Water was introduced in 1856, under municipal control, and is derived by pumping from lake Erie. For this purpose a crib is built in the lake at a distance of 6,661 feet from the shore. It was completed in 1874, and many of the following details were derived from the reports of the trustees for that year.

The protection crib is built of 12-inch square pine timber, 61 feet high, of pentagonal form, each side measuring 54 feet on the exterior and 19 feet on the inner or well wall. Between the two walls is an additional wall. The space between the inner and the outer wall is 24 feet, and the walls are tied together and braced, the face of each being of 2-inch oak plank. The spaces between are filled with stone to a level 12 feet above lake surface. A filling of concrete 5 feet deep, below low-water line, is placed between the outer and middle walls to form a foundation for the stone superstructure which was built thereon in 1878. Stone is piled up against the outside of the crib as a protection against the wash of storms, and the outer side of the crib is also plated for a distance of 5 feet below high water with $\frac{1}{2}$-inch iron as a protection against ice. From this crib, which is surmounted by a government light, a tunnel under the lake extends, in a nearly straight line, 6,661 feet. It is $5\frac{1}{6}$ by 5 feet in diameter, and connects with the crib through a vertical shaft 8 feet in diameter, the bottom of which is $90\frac{1}{5}$ feet below lake surface.



ENGINE-HOUSE, CLEVELAND, OHIO.

At the shore the shaft depth is only $67\frac{1}{2}$ feet, and diameter 8 feet. The construction occupied nearly five years, and, owing to the nature of the ground excavated, was a peculiarly difficult operation. There were 20 feet strata of quicksand in the shafts, and numerous irruptions of water, gas, and clay. The total depth of the crib had to be increased from 44 to 61 feet. The inlet-shaft extends from a short distance below the floor of this crib to the top of the tunnel, and 46 feet of the lower portion is of cast iron 2 inches thick, the rest being $\frac{3}{8}$-inch boiler iron. The top of the shaft is 9 feet below water surface.

From the shore-shaft to the engine-house well a conduit of brick is constructed, oval in section, 4 by 5 feet, and 3,500 feet long. There are two engine-houses, one having been recently built. The former and older contains a pair of regular Cornish engines, erected in 1856, by the Allaire Works, of New York, coupled together, and each of 4,500,000 gallons capacity. The cost complete, with boilers, was $83,000. These engines are 72 inches diameter of steam-cylinder, 30 inches diameter of pump-plunger, 10 feet stroke of steam-piston, 8 feet 9 inches stroke of pump-piston, and run at from 7 to 11 revolutions per minute. One was operated during 116 and the other during 193 days in 1880. They have plain plungers; one suction- and one discharge-valve in each pump, 36 inches in

diameter, of double-beat type. The steam-valves are operated by an eccentric from the main shaft. A spray-condenser is used in connection with each engine, and is 2 feet 8 inches by 4 feet 10½ inches, the air-pump for it being 36 inches diameter by 5 feet 2 inches stroke. The duty has amounted to about 52,000,000 foot-pounds.

To supply steam for these two engines there are two batteries of three Cornish boilers each 6 feet diameter by 30 feet long, with a single 40-inch flue, and evaporating 7½ or 8 pounds water per pound of coal at a pressure of 20 pounds, the fuel being bituminous-coal slack. From this engine-well the water is forced through 2,300 feet of 24-inch main under a head (including friction) of 150 feet into the distributing reservoir. At the engine-house a stand-pipe is erected on this main, as shown in the cut. It is 148 feet high by 36 inches diameter, of boiler iron, encased in brick.

The new pumping-station is directly across the street from the old station, and contains three pairs of pumping-engines, No. 2 being a Henderson duplex compound, similar to a Worthington in appearance, each pump having a capacity of 5,000,000 gallons. It was built by the Cuyahoga Works, of Cleveland, in 1874. The steam-cylinder of each is of peculiar construction, having an annular space 4 inches wide around the piston; this space is cut off from the rest of the interior of the cylinder behind the opposite ends of the piston by a flange which fits the interior of the cylinder, thus separating the steam-space at the ends of the piston from the annular space already described. The cylinder, which is 8 feet long, is divided midway by an annular flange 4 inches high cast on its inside, through which the main body of the piston works steam-tight, thus forming two annular spaces between the opposite ends of the piston, each 4 feet long, in which the steam acts at high pressure. It is admitted at low pressure behind the ends. The steam-cylinder is 56 inches in diameter and the stroke 4 feet, operating a single pump-piston, as in a Worthington, 31 inches diameter by 4 feet stroke. There are 16 suction- and 16 delivery-valves, each 4 by 16 inches, and rising ¾ of a inch in guides. The engines without the boilers cost $52,750. The duty has only reached as high as 37,000,000 foot-pounds, and economically they are considered of no great value as used in these works. They were operated 70 days during 1880, running at a speed of about ten double strokes per minute, and showing a duty of about 29,500,000 foot-pounds. A jet-condenser 3 feet 2 inches by 6 feet is used in connection with two air-pumps in each engine, 28 inches in diameter by 2 feet stroke.

There are two batteries of boilers, one containing four marine and the other two tubular boilers; the former are 8½ feet in diameter by 20 feet long, and contain one hundred and four 4-inch tubes in each. The pressure averages 35 pounds, and the evaporation is 8½ pounds of water per 1 pound of coal. The tubular boilers, with the same evaporation and pressure, are 6 feet in diameter by 16 feet long, and contain seventy-two 4-inch tubes each.

Engines Nos. 3 and 4 are Worthington duplex, the former having been erected in 1876, and the other being just completed. No. 3 cost $47,500, and No. 4, $38,500. They are each of the following dimensions:

High-pressure cylinder, 33¾ inches diameter; low-pressure cylinder, 58¼ inches diameter; pump-plunger, 31 inches diameter; stroke, 4 feet; number of double strokes per minute, 12; capacity, 10,000,000 gallons.

No. 3 was in operation 304 days in 1880, and the duty somewhat exceeded 42,000,000 foot-pounds.

There are, as usual, two air-pumps to each engine, one set being 27 inches diameter, the other 23¾ inches diameter, and all 24-inch stroke.

The four engines in the new pump-house force the water through 1,600 feet of 36-inch main into the reservoir, under a head of 150 feet (including friction).

The reservoir is a rectangular embankment structure 225 feet long by 95 feet wide on the bottom, 300 feet by 175 feet wide at top, depth 21 feet, width of bank 16 feet, with a division-wall of earth 12 feet high faced with brick and puddled. The banks are of earth with a puddled face 2 feet thick, and riprapped with brick laid in cement and 4 inches thick; slope of the inner face, 1½ to 1; outer face, 1¾ to 1; capacity, 6,000,000 gallons. The whole structure is in embankment. The force-main enters through the top of the division-wall. The distribution to 11,563 takers is carried out through $125\frac{3145}{5280}$ miles of cast-iron pipe 36, 30, 24, 20, 16, 12, 10, 8, 6, and 4 inches in diameter. There are 1,000 Matthews hydrants in use. The consumption in 1880 averaged 10,179,461 gallons.

Two hundred and ninety-nine water-meters are in use, and 25 hydraulic elevators; the former are mostly Worthington and Ball & Fitts patents.

The original cost of the works was $550,000, and the cost up to 1881 was $2,630,829. The annual cost of maintenance and repairs was $55,652 for the year 1880.

A quantity of the water taken for analysis from the lake about 3,500 feet from the shore gave, on analysis by Dr. J. L. Cassels, of Cleveland, the following results:

Potassium chloride	grains per gallon	0.086	Magnesium carbonate	grains per gallon	0.488
Potassium sulphate	do	0.090	Peroxide of iron	do	0.038
Sodium chloride	do	0.190	Alumina	do	0.058
Sodium sulphate	do	0.185	Silica	do	0.030
Calcium sulphate	do	2.470	Organic matter	do	0.640
Calcium carbonate	do	1.165			

The presence of lime is due to the fact that the city is built upon a limestone formation.

The repairs to the Henderson engines are expensive every year, it is claimed, and the Cornish engines are old, though still in fair condition.

LOWELL, MASSACHUSETTS.

Lowell is situated upon the Concord and Merrimack rivers, at their confluence, and has a population of 59,475 inhabitants. It is almost entirely a manufacturing city, the chief products being woolen and cotton goods, carpets, stockings, dyed and printed cloth, machinery, and shawls.

The water was introduced in 1872 under the auspices of the city authorities, and is derived from the Merrimack river by pumping, at a point about 1¾ mile above the center of the city. It enters a filtering gallery, located 1,500 feet above Pawtucket bridge, through an inlet-pipe of cast iron, 30 inches in diameter and 220 feet long, with its river-end 45 feet from the river-bank, and built upon a grillage, surrounded by masonry, and fastened by iron bands to a row of piles. This was constructed to be used only when the amount of water passing through the gravel-bank intervening between the filtering gallery and the river was insufficient to supply the demand for water. As some details concerning this method of filtration, which is rare, are of much value, they are given here as derived from personal inquiry of the water-works authorities, and the reports of the commissioners for different years. The distance between the gallery and the river is 100 feet, in which the material is gravel and sand. The gallery is on the north shore of the Merrimack river, and is 1,300 feet long by 8 feet wide and 8 feet high. The intrados of the crown is on a level with the top of Pawtucket dam. Its walls are 2¾ feet thick, of stone in cement, and 5 feet high. The crown is semi-circular, of brick, 1 foot thick, and laid in cement. Stone braces 1 foot square and 10 feet apart are placed on the bottom and bear against the foot of the side-walls. Upon the bottom, coarse gravel 1 foot thick is laid, and all water enters the gallery from below. From 1872 to 1874 this gallery served the purposes of the city satisfactorily, but in August, 1874, after constant pumping for thirty-one days, the water was exhausted, and it was found that about 940,000 gallons per day were being pumped.

On May 10, 1875, the supply again ran short after pumping twenty-one days, the yield being 960,000 gallons per day. At the latter time the water in the river was somewhat higher than during the former trial, which would probably account for the slight difference in the quantity furnished. Taking the area of infiltration surface to be equal to 10,400 square feet, the area of the bottom, the latter quantity would give 92.3 gallons per square foot per 24 hours.

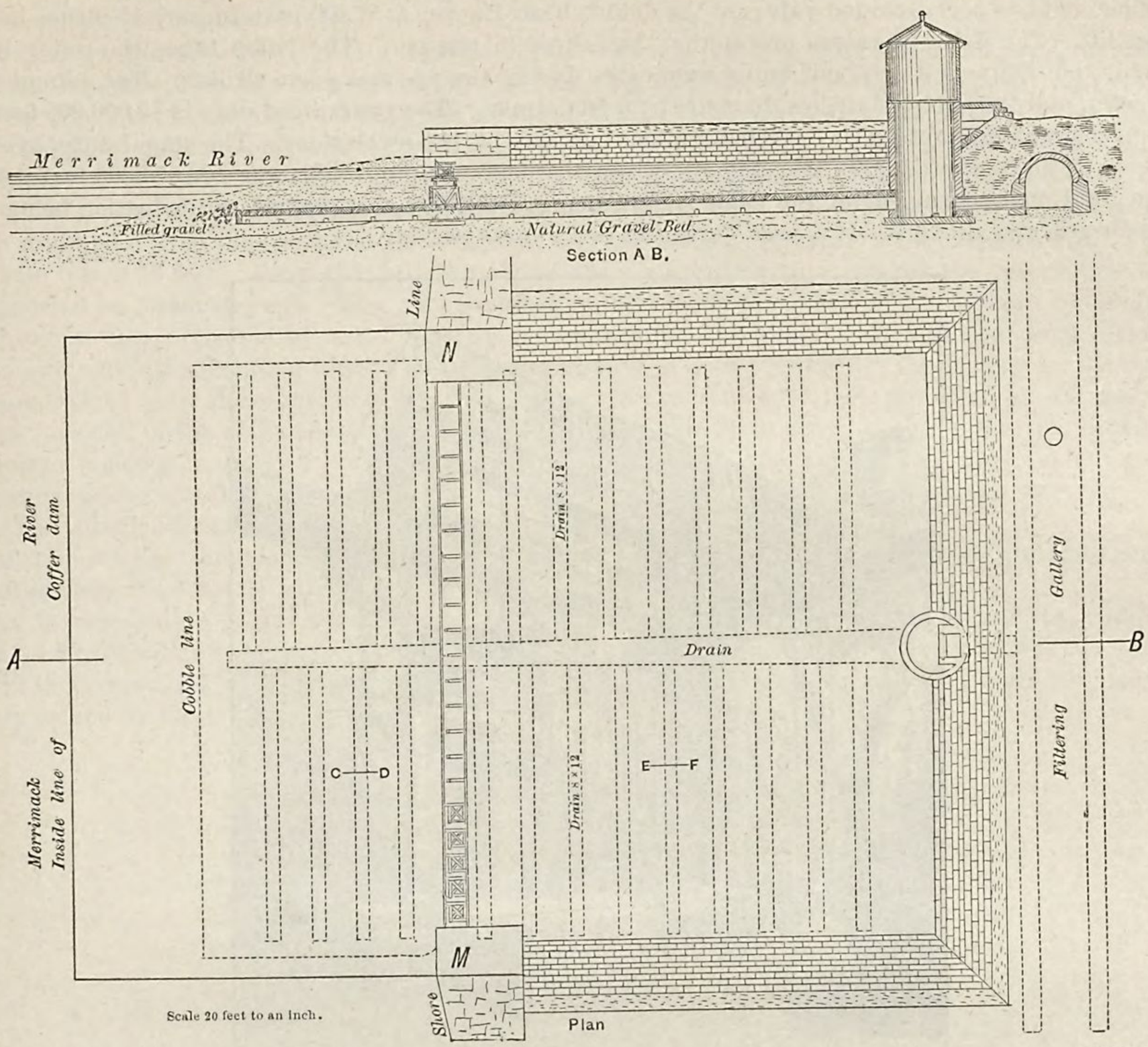
As the consumption had, in 1875, amounted to an average of 1,219,225 gallons per day, it was resolved to construct a filter-bed between the gallery and the river. This was completed in the latter part of the year 1876. The accompanying plan (page 115) shows its mode of construction, with the following details by Mr. Evans, the city engineer:

It is rectangular in plan, with a bottom area of 11,400 square feet. The bottom is graded to an elevation of 24 feet, city datum, encountering a gravel stratum. The well-chamber adjoining the gallery, and seen in the drawing, contains a gate to exclude the water of the filter-bed from the gallery, if desirable. It is of brick, 10 feet interior diameter and 19 feet deep, the bottom elevation being 23 feet. The pipe-connection with the gallery is 30 inches diameter and 12 feet long, of cast iron, entering the latter at the floor-level.

The main drain on line A B of the filter-bed is of stone laid dry, 15 inches square at the river-end, 30 inches square at the well, and 110 feet long, connecting with the well. From this drain 27 lateral drains of similar construction, but 8 by 12 inches in size, extend to the foot of the slopes of the banks, and have a total length of 1,350 feet. These drains are covered in layers with cobble-stones, 36 inches deep, varying from 3 to 8 inches in diameter; screened gravel, 1 to 2 inches diameter, 10 inches deep; gravel, ½ to 1 inch diameter, 2 inches deep; gravel, pea-size, 6 inches deep; coarse screened sand 4 inches deep; and, lastly, fine sand, 18 inches deep. This is shown at section E F on the plan. The top of the last layer is 1 foot below the top of Pawtucket dam at an elevation of 31. On the river side of the bulkhead or trestle-work the layers are laid as in section C D of plan. Ninety-two feet of trestle work divides the filter-bed in two parts at N M, the ends being connected to wooden bulkheads, 8 feet 6 inches by 14 feet 6 inches, filled with earth and stones. Stone wing-walls forming the shore-line extend along the whole front of the bed from these. The sides of the latter are faced like a reservoir embankment with a riprap of granite blocks, sloping 1½ to 1, and extending to within 3 feet of the top of the slopes. Pine plank faces the river side of the trestle down to the cobble-stones, and a platform 4 feet 6 inches wide covers the whole top. To this latter flash-boards are hinged, which, in winter, are laid flat upon the platform and fastened to prevent damage by ice. The area of the bed outside of the trestle-work is 2,850 square feet. This bed furnished a constant supply until 1878, when, for forty-three days in all, it furnished an average daily supply of 1,879,810 gallons. For the rest of the year 1878, or 269 days, the inlet-gate had to be partially opened. Owing to the large amount of silt which the river carries, the deposit in the filter-inlet and on the bed is very large, the former requiring to be cleaned as often as three times in a month. With an area, therefore, of 11,400 feet filtering surface, and the yield calculated at 1,800,000 gallons, we have an average of 158 gallons per square foot as the amount obtainable from the filtering bed.

At the lower end of the filtering gallery an inlet-chamber is built for the purpose of connecting the river inlet-pipe, already described, and the gallery with the supply-pipe or conduit to the engine-house well. This chamber is 17½ feet wide by 38½ feet long, with a 15½ by 13½ foot wing. One portion of the chamber, 8 by 10 feet,

contains a boat for examining the gallery. The chamber contains self-operating gates, two in number, to regulate the supply to the engines. Water can be drawn into the supply-conduit either from the gallery or the river-pipe,



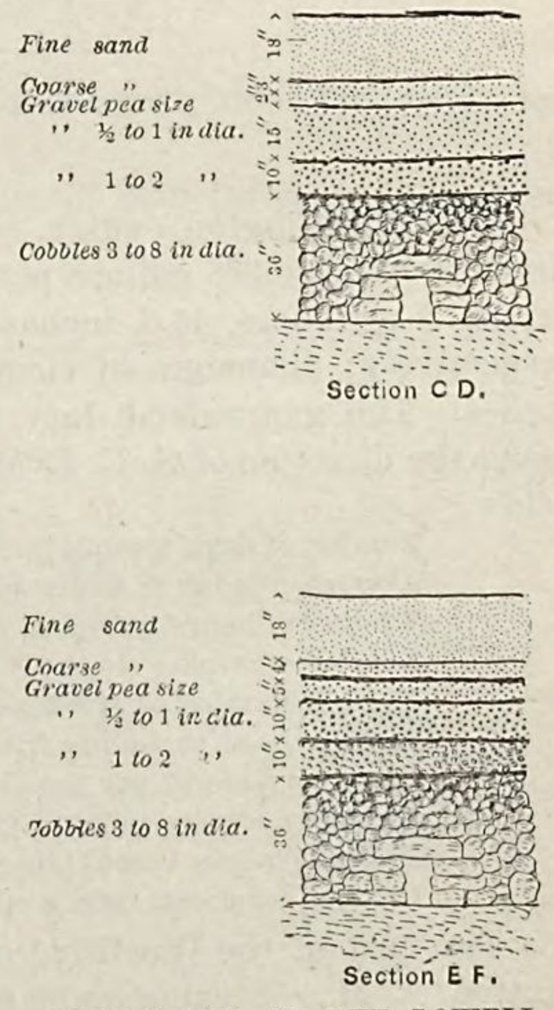
or from both. Screens are placed at the ends of the inlet- and supply-conduit, the latter being double. A brick gate-house covers this inlet-chamber.

The supply-conduit extends 4,182 feet from the inlet to what is known as the terminal chamber. Part of it is tunneled, and the fall of the whole is 9 inches per 100 feet. It is circular brick masonry 4 feet 3 inches interior diameter and 8 inches thick. Two manholes are built into it 1,100 feet apart. About 1,788 feet of it is tunneled in rock.

At the easterly end of this conduit the terminal chamber is located, the top of which is 15½ by 11 feet, and covered by an octagonal brick gate-house. A sluice-gate, operated by hand, regulates the head of water in the outlet-pipe. The latter, known as the pipe-conduit, extends from this terminal chamber to the pump-well of the engine-house. It is a 30-inch cast-iron pipe 6,655 feet long. A part of it crosses a brook 4 feet below its bed by an inverted siphon. The latter is 100 feet long and about 13 feet below water-surface, with a 6-inch blow-off branch, and a manhole pipe connected with its lowest point.

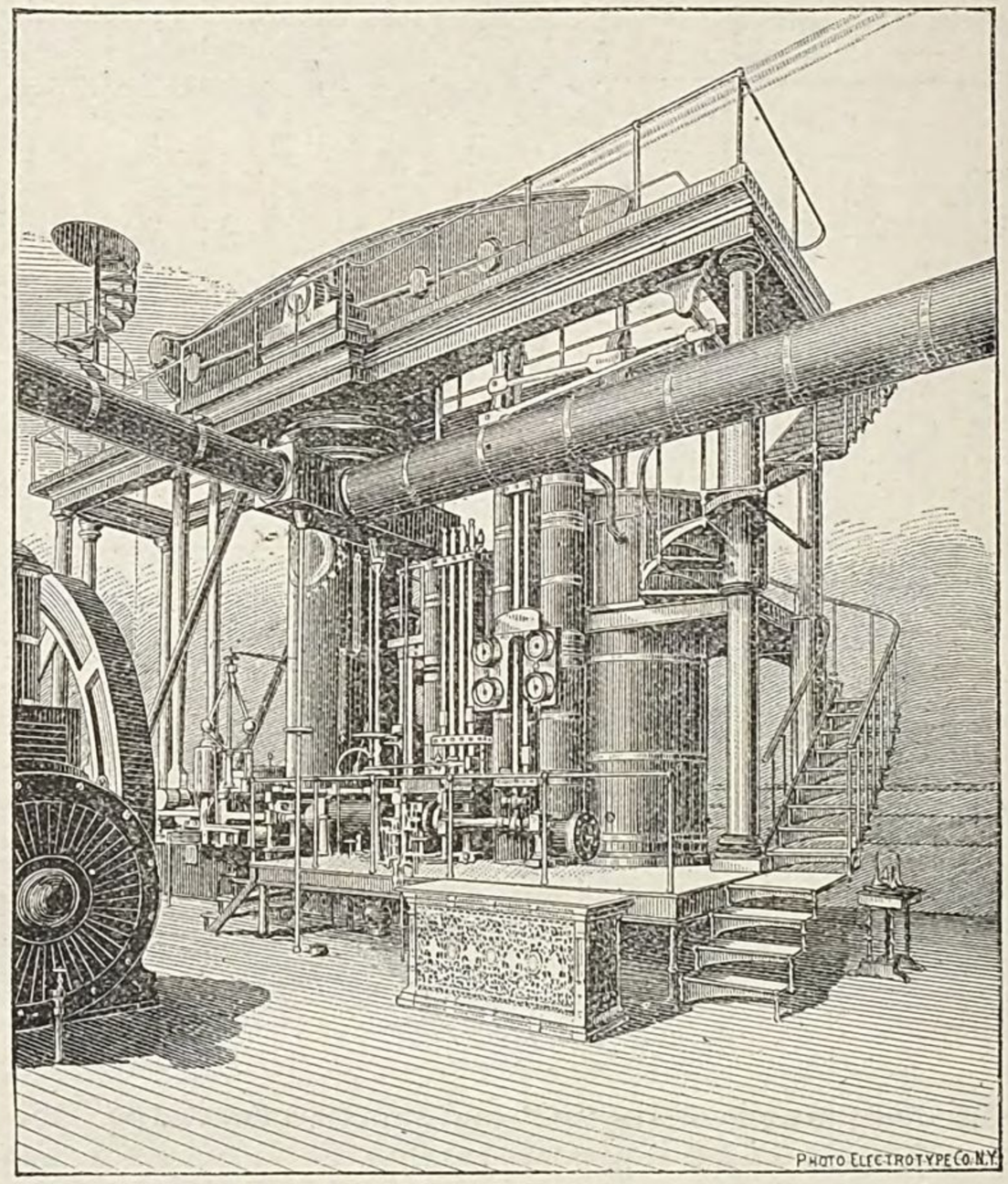
The engine-house is 56 feet 7 inches by 75 feet, and the boiler-house, 41 feet by 56 feet 3 inches; both are of brick.

There are two pumping-engines, one made by H. G. Morris, of Philadelphia, and the other by H. R. Worthington, of New York. The former is a beam and fly-wheel compound condensing engine, with bucket-and-plunger pumps attached. The ratio of expansion from high- to low-pressure engine is 1 to 5. High-pressure cylinder, 36 inches diameter by 60 inches stroke; low-pressure cylinder, 57 inches diameter by 96 inches stroke. The illustration on next page gives elevation and plan of the working parts. The steam-valves, of the double-beat puppet class, are operated by a graduated cam-shaft geared to the driving-shaft. The speed varies from 22 to 26 single strokes per minute. The supporting



FILTER BED OF THE LOWELL WATER WORKS.

column of the beam serves as an air-chamber, with a capacity of 360 cubic feet. The air-pump is 25 inches diameter by 36 inches stroke, and is used in connection with a jet-condenser. The fly-wheel is 25 feet in diameter. The pump-cylinder contains seven suction-valves of the double-beat (Harvey & West) pattern, each 17 inches in diameter and 2 inches lift. The delivery valves are similar, but three in number. The pump takes the water during the up-stroke only, but delivers it in about equal quantities during the up- and down-strokes. The plunger is 25.45 inches diameter, and the pump 36 inches diameter by 6 feet stroke. The guaranteed duty is 75,000,000 foot-pounds, and the capacity was guaranteed at 5,000,000 gallons per day at 11⅔ revolutions. The actual duty, averaged for each month in 1879, computed from the amount of coal used in pumping only, was 100,073,389 foot-pounds, the duty on the total coal consumed for the same period being 78,512,994 foot-pounds, no deduction being made in either case for ashes or clinkers. It is used during 12 or 13 hours per day.



WORTHINGTON PUMPING ENGINE.

The Worthington engine, erected in 1876, to be used when necessary to repair the Morris engine, is also of a capacity of 5,000,000 gallons per 24 hours. The diameter of the high-pressure cylinders is 25 inches; of the low-pressure cylinders, 43.3 inches; length of stroke, 48 inches; diameters of pump-plungers, 22½ and 22 inches, respectively; diameters of air-pumps, 27 and 30 inches, respectively; stroke, 24 inches; jet-condenser, 35 by 72 inches. The guaranteed duty was 65,000,000 foot-pounds; average speed, 12 revolutions per minute. A trial under the direction of G. E. Evans, city engineer, in 1876, gave 69,000,438 foot-pounds. Its record for 1879 is given below:

Number of days' pumping	41
Average number of hours' pumping per day	10.9
Number of hours' pumping per month	448.25
Number of strokes made per month	280,206
Average number of strokes made per minute	10.42
Average head, including friction, in feet	163.63
Quantity pumped per month, in United States gallons	86,863,860
Average quantity pumped per day, in United States gallons	2,118,631
Duty in pounds, 1 foot high, with 100 pounds coal, used in pumping only, no deduction for ashes or clinkers	74,136,672
Duty on total coal consumed, no deduction for ashes or clinkers	59,862,329

The cost of the Worthington engine was $34,250. (For further details of these engines, see report of F. R. Hutton, E. M., "Steam-pumps and pumping-engines," Vol. XXII of Tenth Census.)

The cost of the Morris engine is approximated at $70,000. It is run under 50 pounds of steam; cut-off at one-quarter; evaporation of boilers, 9.61 pounds of water per pound of anthracite coal. The steam to both engines is supplied by a battery of three multitubular boilers, 16 feet long by 6 feet diameter, containing 94 brass 3½-inch tubes in each, and a heating surface of 1,000 feet. Two are used at a time; each has a grate-surface of 25 square

feet. One small 10-foot boiler is used to heat the jackets of the Worthington cylinders. These pumps force water from the pump-well through 2,666 feet of cast-iron pipe 24 inches diameter into the distributing reservoir under a head at the pumps of 165½ feet.

The reservoir, located within the city limits, on Sixth street, is partly in excavation and partly in embankment. In shape it is a square with two corners cut off, 520 feet long, 510 feet wide, and 24 feet deep; high-water surface 4 feet below the embankment top and 181½ feet above datum; covers 7 acres; water-surface, when full, 5.2 acres; capacity, 30,000,000 gallons; only one compartment; slopes of the banks, 1½ to 1 inside and 2 to 1 outside; interior slopes puddled 2 feet thick, covered 1 foot thick with broken stone, and a granite riprap laid upon it 15 inches thick. A base course of 1 foot 6 inches forms the foot of the slope-wall. The whole bottom is puddled 1 foot deep. A 12-inch drain-pipe from the southeast embankment serves to empty the reservoir for repairs, etc. The width of the banks on top is 15 feet. From the gate-chamber a 30-inch cast-iron pipe crosses the reservoir to the eastern bank, supported on masonry piers. The gate-chamber is located on the inside of the western embankment; it is divided into two compartments by a wall 3 feet 6 inches forming the influx- and efflux-chambers. The former is divided in two with an adjustable weir to measure the amount of water pumped. From the weir the water passes through the 30-inch pipe above mentioned. Two sluice-gates, each 2½ by 3 feet, protected by screens, are placed in the reservoir-wall of the efflux-chamber, one above the other, for use in drawing the water from different depths. An opening or sluice-gate, 2 feet 6 inches by 3 feet 4 inches, in the main division-wall, between influx- and efflux-compartments, allows water to be pumped direct into the distributing mains through the reservoir. The whole gate-chamber is built of cut granite and is 26 feet square.

The distributing system embraced, in 1879–'80, 320,286 feet of cast-iron and of wrought-iron and cement pipes. Of the latter there are but 4.31 miles. The sizes are 30, 24, 16, 12, 10, 8, 6, and 4 inches.

Water is supplied to 11,427 water-takers. The original cost of the works was $1,266,766, which has been increased to $2,156,032 on January 1, 1880. The annual cost of maintenance and repairs was, for 1879, $21,228. Up to 1880 there were 653 fire-hydrants made by the Boston Machine Company, and 584 meters, divided as follows, and mostly owned by the takers:

Varieties of meters.	⅝-inch.	¾-inch.	1-inch.	1½-inch.	2-inch.	3-inch.	4-inch.		Total.
H. R. Worthington, New York	336	25	48	3	5	2	2	.....	421
Union Water Meter Company, Worcester (Ball & Fitts)	30	21	1	1	1	.....	.....	.....	54
Fitts rotary	62	18	7	2	1	.....	.....	.....	90
W. E. Desper & Co., Worcester	13	2	2	.....	.....	.....	.....	.....	17
"Standard"	1	.....	.....	.....	.....	.....	.....	.....	1
Motor register	.....	.....	.....	.....	.....	.....	.....	1	1
Total	442	66	58	6	7	2	2	1	584

It is claimed by the engineer that the Morris engine has cost but 22 cents per 1,000,000 gallons for repairs for several years. The consumption for 1879 averaged 2,024,768 gallons per day.

Analyses of the water, by Professor W. R. Nichols, are appended. An examination of them leads one to suppose that some water enters the gallery from the land side, increasing the hardness.

The engineer in charge of the works is Mr. Horace G. Holden.

Locality.	Date.	Ammonia.	"Albuminoid ammonia."	Solid residue of filtered water (a): Inorganic.	Organic and volatile.	Total.	Chlorine.	Sulphuric acid.	Silica.	Alumina and oxide of iron.	Lime.	Magnesia.	Oxygen, cubic inches to the gallon.
Merrimack river, opposite inlet-chamber (b)	September 2, 1873	0.0027	0.0089	1.03	1.35	2.38	0.08	.....	.....	.....	.....	.....	.....
Do	September 10, 1873	0.0027	0.0060	0.91	0.84	1.75	0.06	0.20	0.29	c 0.18	0.32	Trace	.....
Do (d)	September 10, 1873	0.0026	0.0058	1.05	1.07	2.12	0.07	.....	.....	.....	.....	.....	e 0.43
Do (f)	January 1, 1874	0.0031	0.0058	1.45	1.17	2.62	0.12	.....	.....	.....	.....	.....	g 1.82
Inlet-chamber, gallery	September 2, 1873	0.0008	0.0016	2.82	1.05	3.87	0.14	.....	0.23	0.12	0.50	Trace	.....
Do	September 10, 1873	0.0008	0.0012	2.71	0.68	3.39	0.12	0.16	0.57	0.08	0.57	Trace	e 0.16
Do	January 2, 1874	0.0038	0.0022	3.04	0.70	3.74	0.15	.....	.....	.....	.....	.....	g 0.64
Engine-house	September 2, 1873	0.0012	0.0033	3.29	0.84	4.13	0.22	.....	.....	.....	.....	.....	.....
Water as delivered in Lowell	July 10, 1873	0.0012	0.0039	3.06	0.86	3.92	0.18	.....	.....	.....	.....	.....	.....
Do	January 2, 1874	0.0022	0.0020	3.67	0.72	4.39	0.18	.....	.....	.....	.....	.....	g 1.72

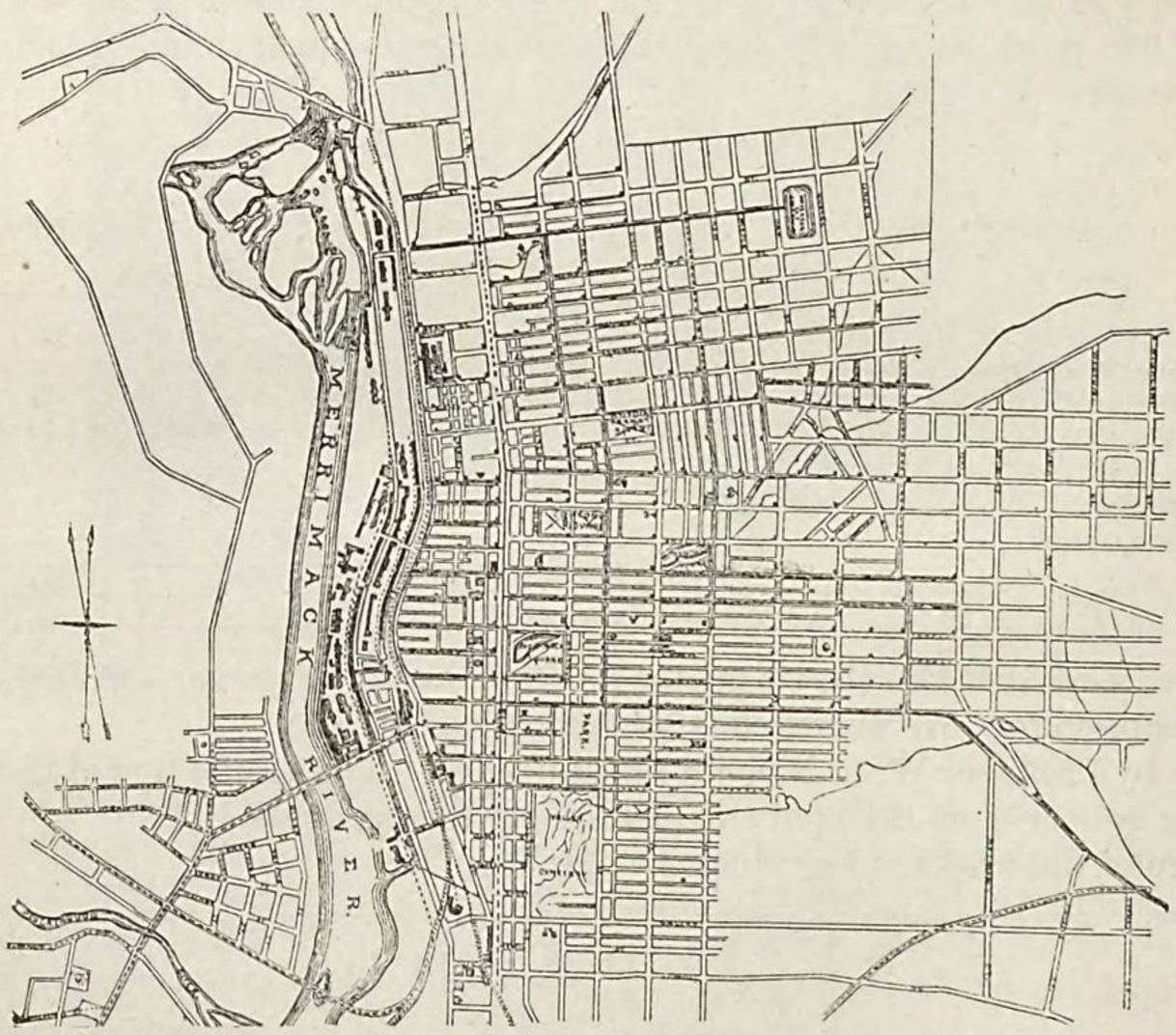
a Filtered through filtering paper.
b Water taken 100 feet from shore, 1½ foot below surface. The unfiltered water contains: inorganic matter, 1.17; organic matter, 1.40; total, 2.57.
c Trace of phosphoric acid.
d Water taken 100 feet from shore, 6 feet below surface.
e These determinations were made on the spot.
f Water taken 100 feet from shore, 7 feet below surface.
g These determinations were made in the laboratory.

7.—PUMPING BY WATER-POWER.

MANCHESTER, NEW HAMPSHIRE.

Manchester contains a population of 32,630, and is located on the east bank of the Merrimack river near its confluence with the Piscataquog. At this point it has a drainage area of 3,000 square miles. The interests of the town are almost exclusively manufacturing, the chief products being woolen and cotton goods. It is the most important city in the state.

The city is laid out with great regularity, as may be seen from the accompanying map, and is comparatively level.

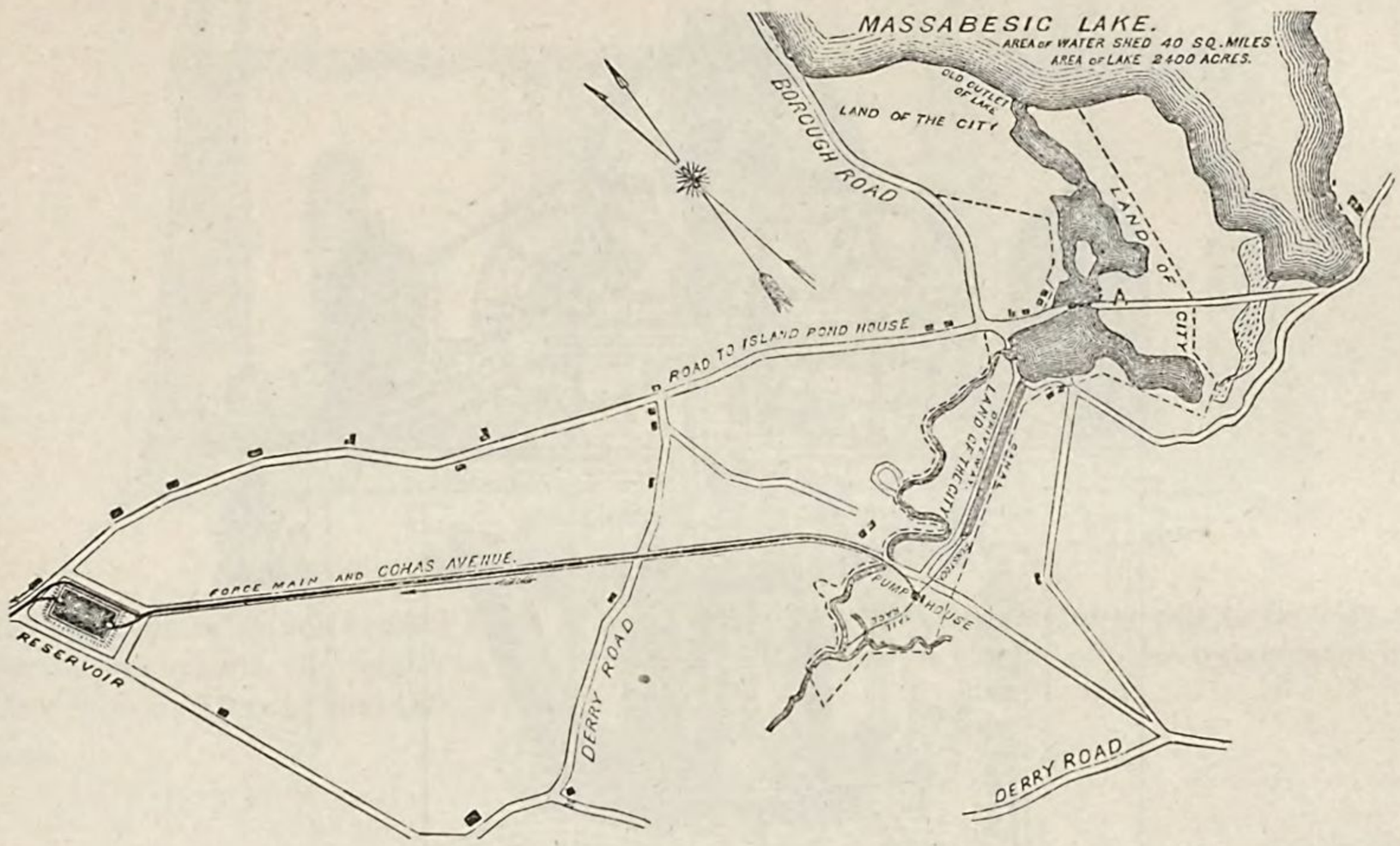


MAP OF THE CITY OF MANCHESTER.

The water-supply introduced in 1874 by the city authorities is derived by pumping from lake Massabesic, situated about 4 miles east of the city. This lake has a water-shed of 45 square miles, and an area of water-surface of 2,350 acres, with a circumference of 20 miles. According to Mr. Fanning, chief engineer, the surface of the adjoining country is hilly, with impervious soils and but little meadow-land in the vicinity, and the shores of the lake are somewhat abrupt. This lake has been utilized for supplying the city with water by damming its outlet with a rough dam, producing a head of water of 24 feet by which to operate a set of turbines driving the pumping machinery. The average daily flow from the lake is 40,000,000 gallons. The head produced by the flash-boards of the lower dam, or the total depth of the lower pond below the main dam which can be drawn upon at present, is about 3 feet. The average yield of the lake for domestic purposes, when utilizing it as power in pumping, is estimated at 8,000,000 gallons per day raised into the reservoir. The 3 feet additional depth produced by the lower dam are equivalent to an increase of storage of 2,345,000,000 gallons.

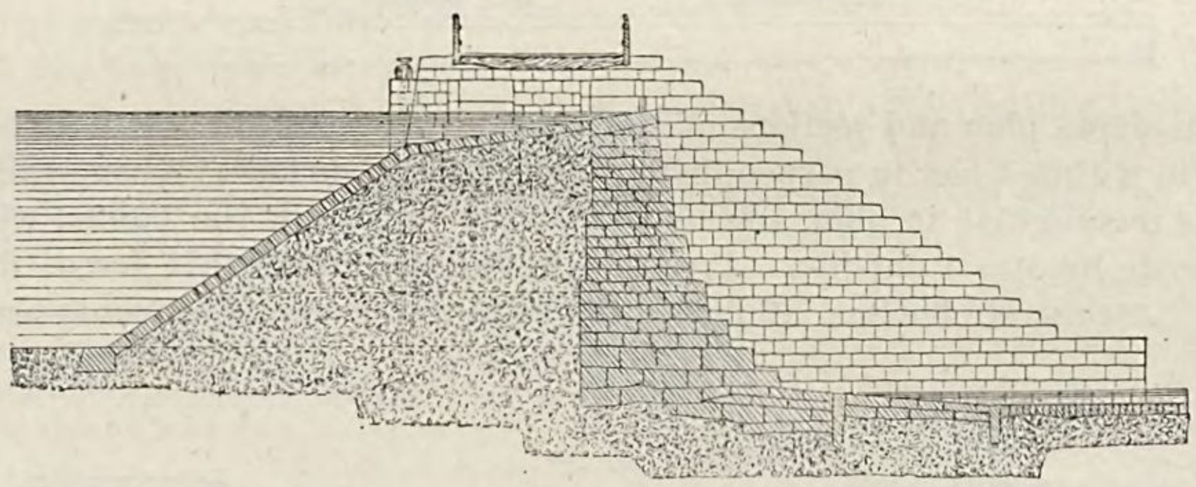
The main dam is located at A (see diagram on next page), about 3,000 feet below the old outlet of the lake. The dam is shown in section. Its total length is about 225 feet; width of top of banks, 22 feet; total height of dam,

28 feet. The waste-weir or overfall is 42 feet long, of masonry, with a series of 7 steps on the lower side to break the fall of the overflowing water, a fall of 24½ feet. The sides of the overfall are protected by abutments. Beyond these the dam is of earthwork, with a masonry priming-wall 2½ feet thick at top and sloping 1 to 16. A riprap of



MANCHESTER WATER-WORKS.

stone faces the upstream side, and the lower side is grassed, both sloping 1½ to 1. A vertical masonry wall rises from the face 2 feet below high-water mark to a height of 7 feet, making the width of the banks 22 feet, upon which a roadway is constructed. The overfall is spanned by a bridge.



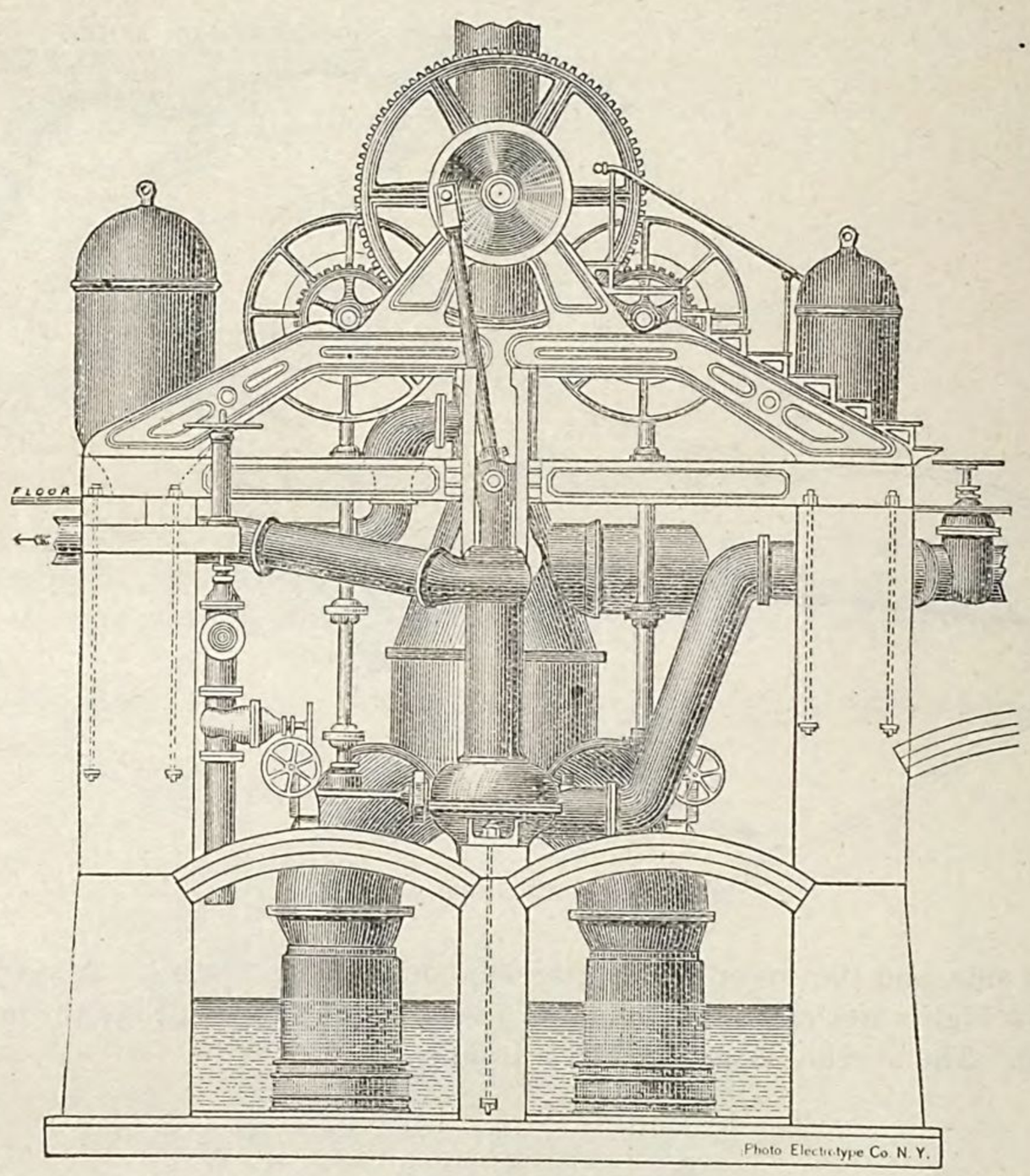
DAM OF THE MANCHESTER WATER-WORKS.

The water, flowing from the above-described dam, extends itself over the lower pond shown in the plan, and at the outlet to this is erected the rough wood-and-stone dam mentioned. From here an open ditch conveys the water about 1,000 feet to the head of an excavated canal, one end of which can be seen in the accompanying sketch. This canal is about 16 feet deep by 1,470 feet long by 35 feet wide at top. From the lower end of it, controlled by gates and protected by screens, the circular wooden penstock extends to the pump-house.

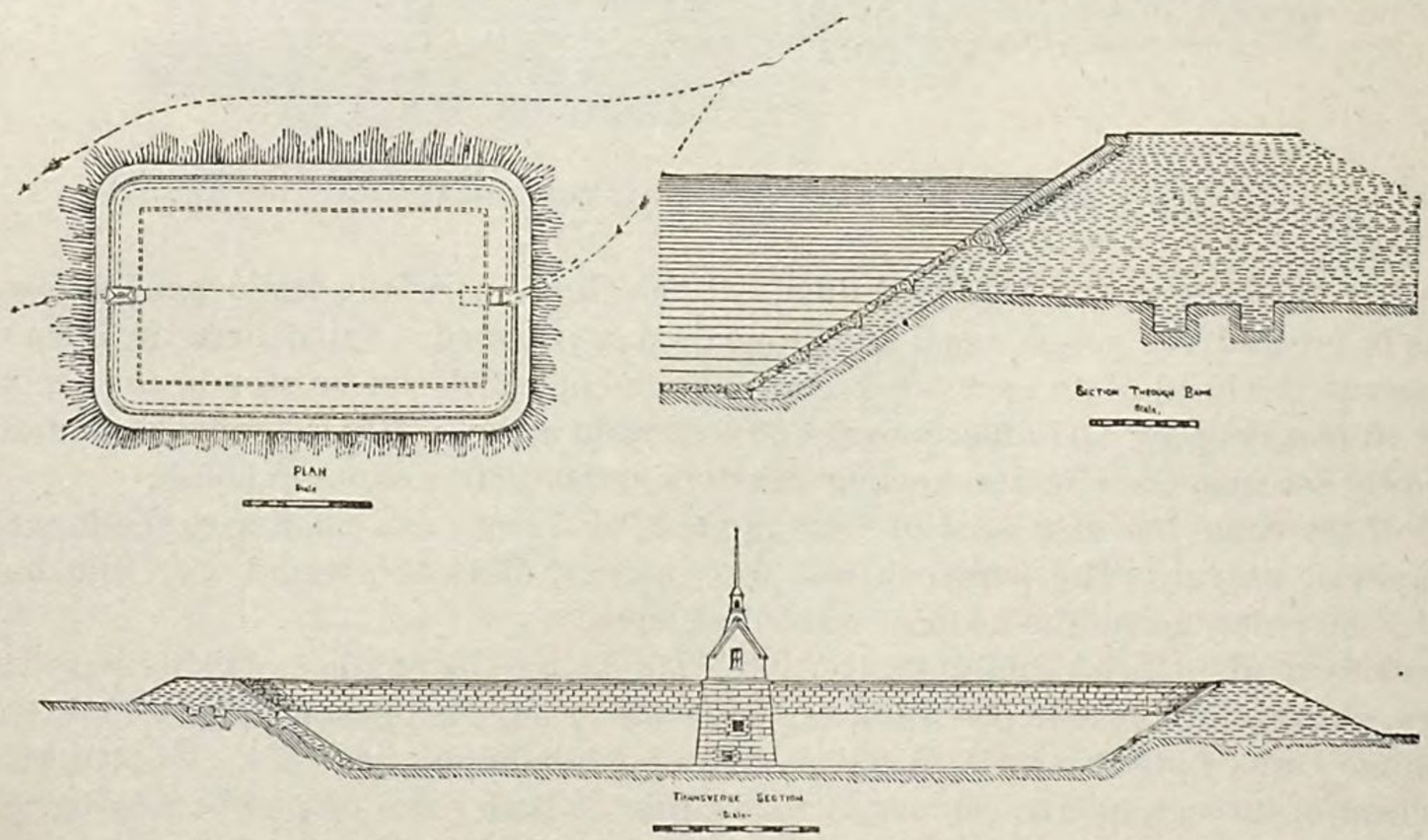
The upper end of the canal has also a set of four gates, 3 by 5 feet each, similar to the lower ones. The sides of the canal are unpaved as yet. The penstock is 6 feet internal diameter, bound with iron hoops, and 716 feet long. At its foot in the pump-house the head of water is 40 feet.

The pump-house is a plain brick building, the left wing being the engineer's dwelling. It contains a set of pumping machinery, shown in plan and elevation on page 120, which is operated by two Geyelin turbines. The whole set of machinery was built by R. D. Wood & Co., of Philadelphia, in 1874. The turbines are 36 inches diameter, under a head of 40 feet, and so connected that either or both pairs of pumps may be run. The pumping machinery contains two pairs of upright pumps of the bucket-and-plunger type, with four 16-inch cylinders, 40 inches stroke, and 11¼-inch plungers, each pair having a capacity of 2,500,000 gallons each, and running at an average speed of 18 revolutions per minute. They are run constantly. The pressure on the pumps in lifting to the reservoir is 110 pounds per square inch. The pump-valves are double-beat.

From the pump-house a cement-lined wrought-iron force-main, 20 inches in diameter and 8,170 feet long, leads to the distributing reservoir. This is situated at the "Centre", at an elevation of 152 feet above Elm street at the city hall, making a lift of 113 feet above the high-water level in the lake.



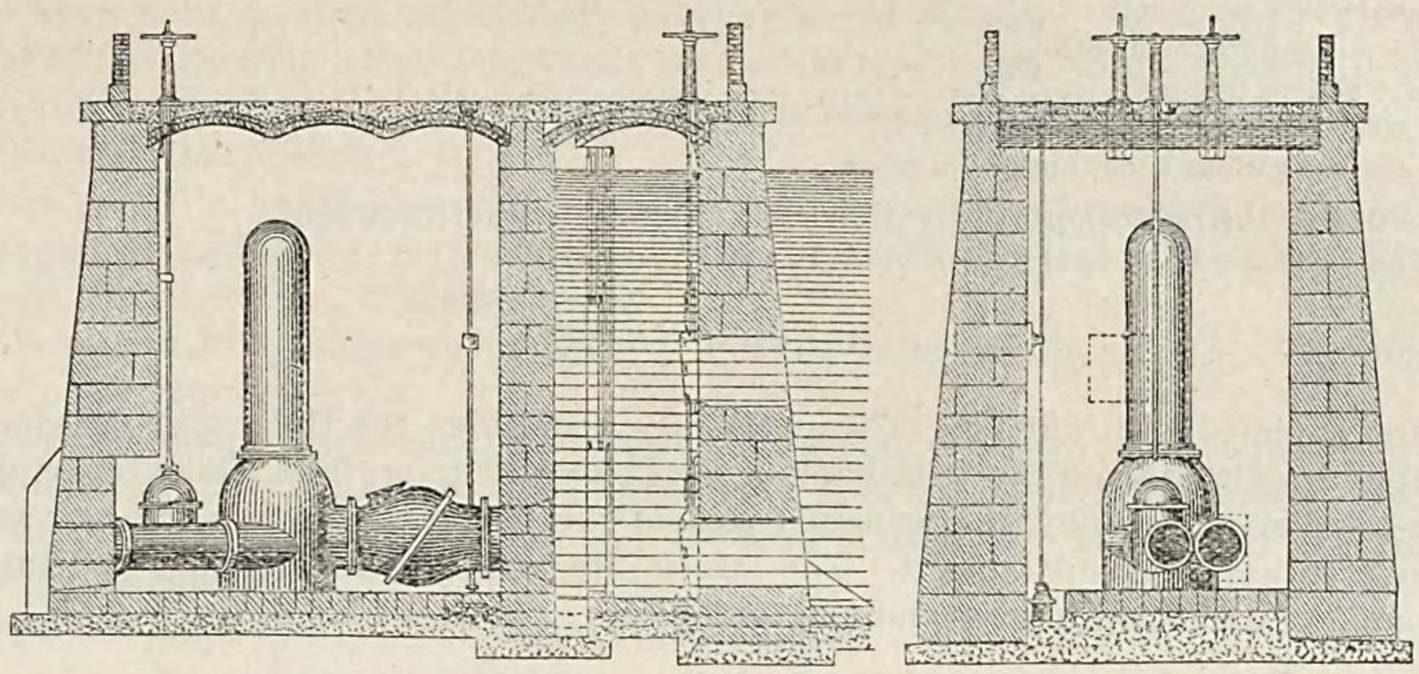
The annexed diagram shows plan and sections of the distributing reservoir. It is in earthwork with concrete face 10 inches thick, laid to within 4 feet in perpendicular depth of the surface. Above this the slope is faced with masonry in cement. It is rectangular in plan, 460 by 265 feet at the top of the banks, which have a width of 18 feet, and slope 1½ to 1 inside by 3 to 1 outside. Area of high-water surface, 2.75 acres; depth, 19 feet; capacity, about 13,500,000 gallons. A concrete bottom (12 inches thick) to the reservoir prevents leakage.



DISTRIBUTING RESERVOIR OF THE MANCHESTER WATER-WORKS.

The force-main enters the inlet-chamber at the southern end of the reservoir. In this is a measuring-weir and inlet-sluice, over which the water may be passed into the reservoir. At the opposite or northern end is the effluent-chamber, shown in the cut on page 121, the arrangement of the gates, etc., being there given.

The force- and supply-mains are directly connected around the reservoir, as shown, a gate being placed in the connection just beyond its junction with the force-main to enable the water to flow into the distribution mains without passing through the reservoir.



DISTRIBUTING RESERVOIR—SECTIONS OF EFFLUENT CHAMBER.

From the reservoir a 20-inch cement-lined wrought-iron pipe, 6,800 feet long, extends to the city mains.

The distribution system, the total length of which is given below, is carried out through cement-lined wrought-iron and a few thousand feet of cast-iron pipes.

Cement-lined pipe.	Feet.	Cast-iron pipe.	Feet.
20-inch	20,934.90	20-inch	104.00
14-inch	6,825.00	14-inch	4,925.00
12-inch	8,400.00	12-inch	6,002.00
10-inch	5,131.75	10-inch	532.00
8-inch	12,644.00	8-inch	2,346.00
6-inch	82,734.50	6-inch	14,949.00
4-inch	8,950.00	4-inch	989.00
Total	145,620.15	Total	29,847.00
Equal to $27\frac{3060.15}{5280}$ miles.		Equal to $5\frac{3447}{5280}$ miles.	

Total of cast-iron and cement-lined pipe, $33\frac{1227.15}{5280}$ miles.

Three hundred and five hydrants made by the Boston Machine Company are in use up to date, with 257 gates.

The consumption averages 1,250,000 gallons per day, delivered to 3,950 families through 1,800 service-pipes, at an annual cost for maintenance and repairs of $11,600 for 1879.

The first cost of the works is given at $614,000, the main dam having cost $101,198. This has been increased to $742,128 up to January, 1880, divided as follows:

Land and water-rights	$30,858 67
Dam, canal, penstock, and race	101,198 20
Pumping machinery, pump-house, dwelling, etc	88,493 96
Distributing reservoir and fixtures	71,542 36
Force- and supply-main	88,674 02
Distribution pipes	245,106 51
Fire-hydrants and valves	30,149 99
Tools and fixtures	10,649 35
Boarding- and store-houses	919 36
Roads and culverts	2,084 24
Supplies	550 39
Engineering	22,176 19
Livery and traveling expenses	2,856 64
Legal expenses	563 79
Grading and fencing	11,349 62
Service-pipes	27,247 49
Meters, boxes, and brass connections	7,707 72
Total construction account	742,128 50

The analysis of water from lake Massabesic, as made in 1869 by S. Dana Hayes, state assayer of Massachusetts, shows the following results:

	Grains in 1 U. S. gallon.	Parts in 100,000.
Vegetable organic matter	1.66	2.77
Mineral matter	1.16	1.93
Total	2.82	4.70

Hardness (Clark's scale), 0.84.

The record of the pumping-engines for the year 1879 and cost of pumping is thus stated:

Number hours' work for both pumps	7,586.33
Average strokes per minute	15.83
Total number strokes per month	7,205,364
Total gallons pumped in one month	455,094,062
Daily average gallons pumped	1,246,913

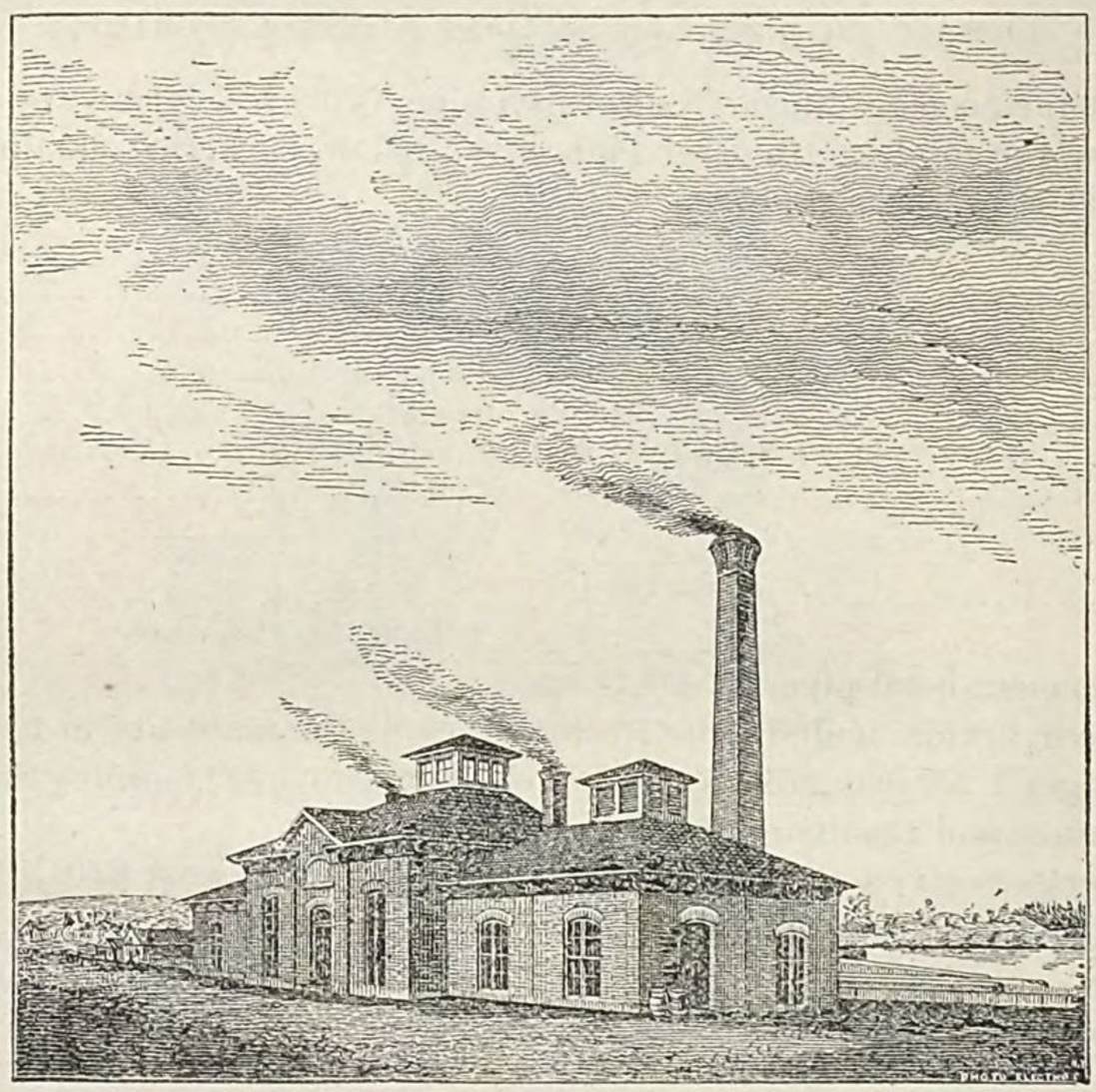
Cost of raising 1,000,000 gallons into reservoir, $2 78.

Cost of raising 1,000,000 gallons 1 foot high, 2.46 cents.

The works are under the direction of Mr. Charles K. Walker, superintendent.

BANGOR, MAINE.

Bangor was first supplied with water in 1876 by the city authorities, the Holly system being adopted. It is a city of 16,856 inhabitants, situated on the west bank of the Penobscot river, from which the supply is derived. It is exceedingly irregular in topography, the principal part of the business streets being in a valley with hills of considerable altitude entirely encompassing it. The streets are more or less regularly laid out, and the industry of the place is shaping or exporting lumber and ship-building.



PUMPING STATION, BANGOR WATER-WORKS.

The pumping-station is located on the west bank of the river, about 1½ mile from the heart of the city, to the north. At this point a wooden dam is built across the river, raising its surface 8 feet. The drainage area of the river above this is estimated at about 7,200 square miles, with a mean annual rainfall of 42 inches.

The power to drive the pumps is derived from the fall of from 6 to 12 feet, driving three American turbine water-wheels, each 7 feet in diameter, using 110 gallons per revolution, and run two at a time. These are geared to an improved Holly pumping-engine of four cylinders. There are two of the latter, 21 inches in diameter and 30 inches stroke, and two of 14 inches in diameter by 24 inches stroke. They are so arranged that two may exhaust into the condenser after using the exhaust-steam from the other two, or all may be used at high-pressure. They are run at 20 revolutions per minute for the ordinary domestic pressure of 110 pounds per square inch during the whole of the year, and can be increased to 120 revolutions.

The pumps are geared to this engine or to the water-wheels at pleasure. There are four plungers, 12 inches in diameter by 27 inches stroke, making from 7¼ to 10 double strokes per minute each. The pump-cylinders contain 12 inlet- and 12 outlet-valves each, with a lift of ⅞ inch, 2 inches diameter by 12 inches long, of wood, and cylindrical in form.

The steam-cylinder valves are of the ordinary Holly pattern. A single-acting air-pump, 14 inches in diameter by 14 inches stroke, and a jet-condenser in the shape of a rectangular parallelopiped, 3 by 3 by 1½ feet, are connected with the engine. The cut-off valves are puppet-valves, the main valve being a slide-valve.

Steam is supplied from a battery of two horizontal multitubular boilers, 5 feet in diameter by 15 feet long, under a pressure of 80 pounds per square inch. They contain fifty-six 2-inch tubes each; the fuel used is wood. Steam is used in pumping only when accident or other cause prevents the use of the water-wheels. The Holly system seems to have been adopted here chiefly as a matter of economy. No source of supply exists within a moderate distance of the city from which a sufficient head could be obtained without pumping, and it was considered too expensive to build a reservoir for the distribution. It is one of the few instances in which water-power is available to do the work free of cost.

A Holly rotary pump is held in reserve for use in case repairs are necessary to the main pumps. This is capable of discharging 16 gallons per revolution, and is run at a velocity equal to five times that of the main engine. Diameter of suction and discharge, 12 inches inside.

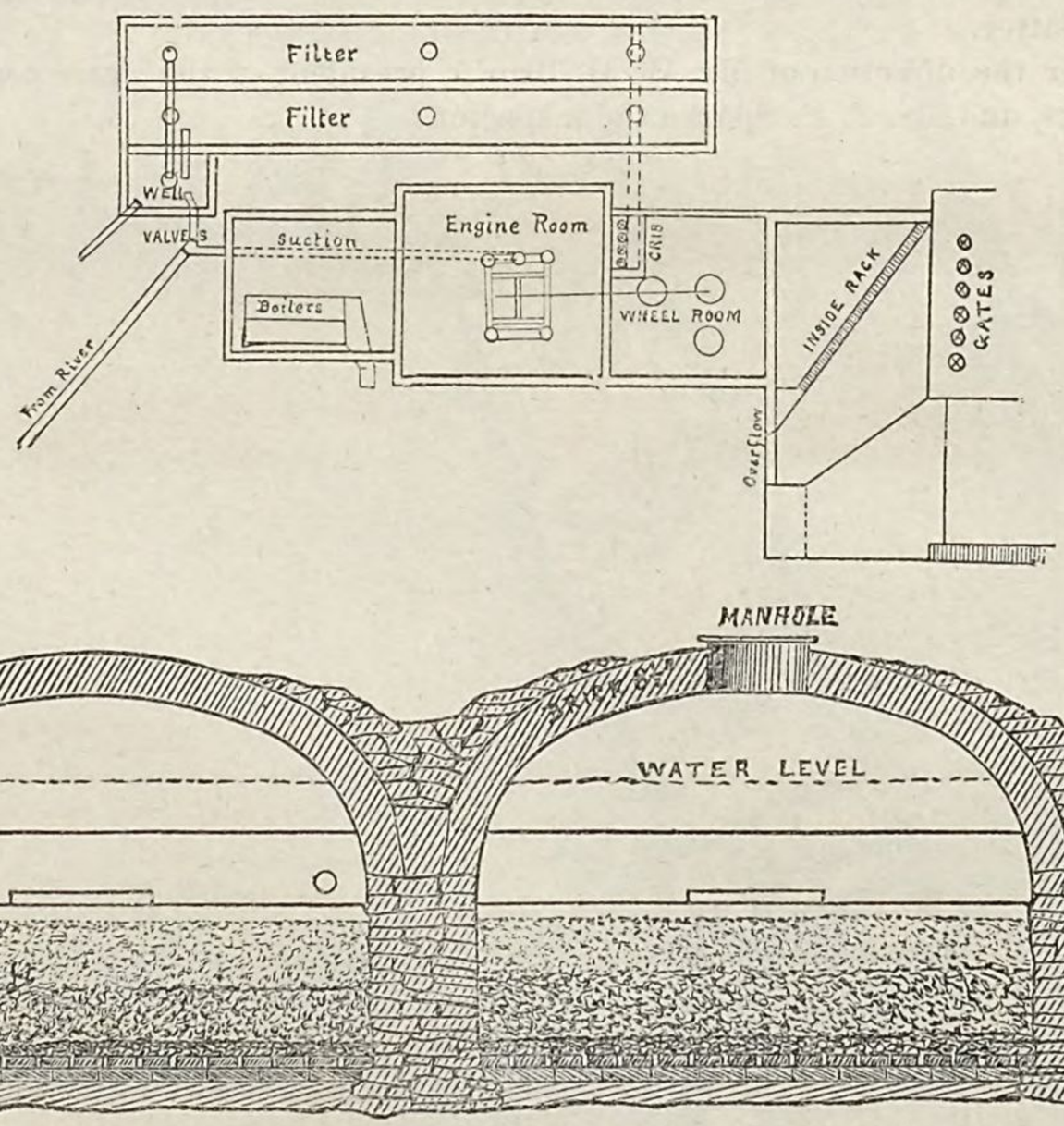
The cost of the engine and pumps was $17,000, and of the water-wheels $13,000. The time spent in repairs is calculated at about five hours per year.

The water from the pumps enters the city through 5,316 feet of cast-iron main, 16 inches in diameter, and there connects with 23 miles of distributing cast-iron mains of 4, 6, 8, and 12 inches diameter. On this latter system there are 155 Holly hydrants for fire purposes, and about 70 stop-gates. The capacity of the pumping-engine is 4,000,000 gallons per 24 hours.

The length and dimensions of the pipe in use are as follows:

	Feet.
16-inch	6,110.6
12-inch	4,347.5
8-inch	19,697.2
6-inch	40,414.9
4-inch	31,000.5
3½-inch	175.0
2-inch	14,592.7
1-inch	205.0
Total	116,543.4

A filtering chamber is employed to purify the water before its entrance into the force-main. Two chambers, side by side, each 153 feet long by 12½ feet wide, end in a well-chamber 14 by 24 feet, from



BANGOR WATER-WORKS—SECTION OF GALLERY.

which the water is taken by the pumps. The gallery is parallel to the pump-house and closely adjoining it. The water enters it from above the dam, through the wheel-pit, at a point midway between its surface and bottom. From the wheel-pit, in one corner of which is a confined crib, the water is conveyed through four gates into a

trough of wood, and thence into the filter-chambers, with stop gates so arranged that it can be cut off from either chamber or from both. In the crib is an octagonal revolving screen (one revolution every ten minutes), 12 feet long, of wire-cloth with 35 meshes to the inch. It is attached to the shaft, and, by revolving, is self-cleansing.

The water enters the filter-chamber above the level of the filtering material, flows over its surface, and downward through 3 feet of gravel and sand into drains below, and then passes to the pump-well. The arrangement of pump-house and filter, etc., is shown in the accompanying sketch.

The consumption of water from March 1, 1879, to March 1, 1880, was as follows:

	Gallons.
March	21,886,700
April	23,704,780
May	24,982,320
June	21,326,800
July	14,459,940
August	19,065,310
September	14,129,500
October	13,992,000
November	17,965,310
December	20,022,200
January	24,337,500
February	24,227,500
Total	240,099,860
Average for each day	656,011

The consumption occasionally reaches a little over 1,000,000 gallons, as indicated by registers at the pumps. The filters are cleaned annually of a sediment about ¼ inch thick. About 4 feet of water is over the filtering bed at all times.

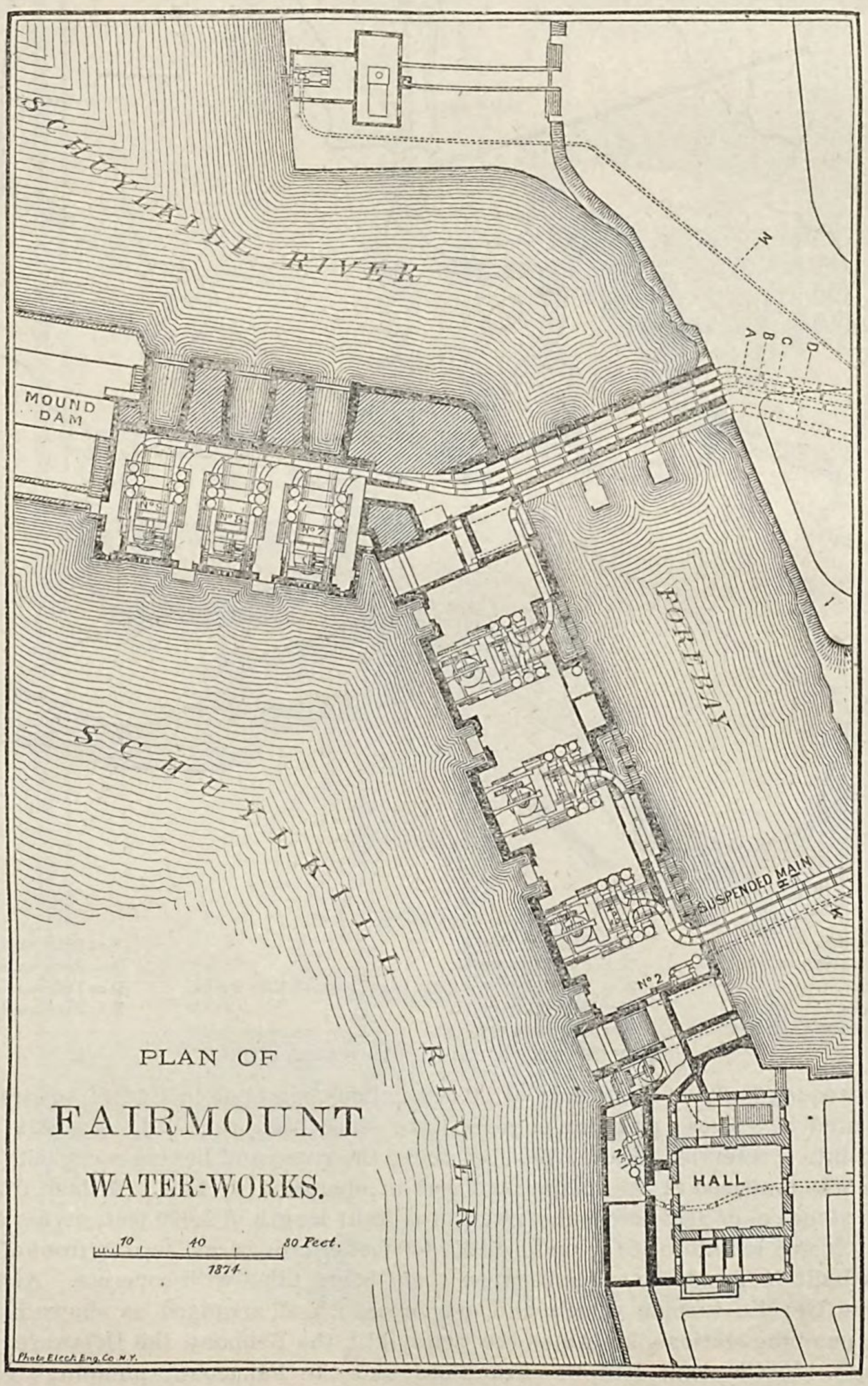
The original cost of the works was $200,000, which has increased to a total cost at the present time of $487,022, with an average cost of $15,000 per year for maintenance and repairs. Very few meters are used as yet. The water can not be said to be very pure. In quantities, it has a decidedly brownish tinge. At the point where it discharges over the roll-way of the dam this color is darker than any I have elsewhere encountered. It is probably due to the presence of organic matter transported from the upper portion of the river, as it is translucent and unlike the water encountered in rivers such as the Ohio and the Mississippi. It has also a peculiar taste, at times similar to decayed organic and vegetable matter.

The works are under the direction of Mr. W. H. Brown, president of the water board; Mr. W. W. Fellows is the engineer at the works, and Mr. F. E. Sparks the inspector.

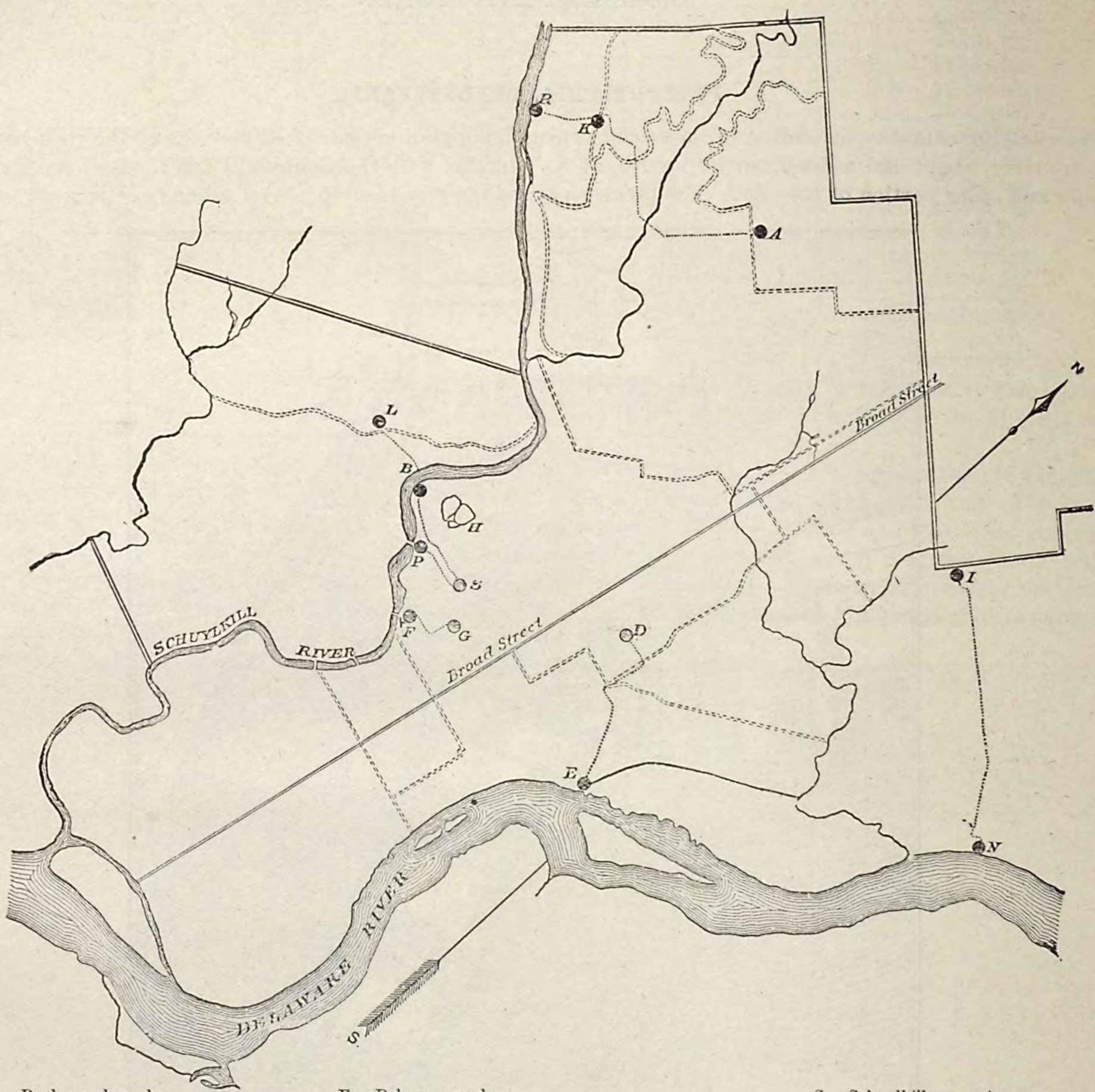
8.—COMBINATIONS.

PHILADELPHIA, PENNSYLVANIA.

Philadelphia contains, according to the recent census, a population of 847,170, and lies on the west bank of the Delaware river, about 100 miles from its mouth, at its junction with the Schuylkill river. Between the two lies the main and older portion of the city. The greater part of the city is on low level ground. Parts of the suburbs



are, however, considerably elevated. The average height of the main portion above datum is 40 feet. The substratum of the city is largely made up of alluvial deposit. The city is rectangular in plan, with the principal streets running east and west, and is chiefly a manufacturing and residence city. Water was first introduced into the main streets in 1801, the supply being derived from the Schuylkill river. The works consisted, first, of a basin on the Schuylkill river, 84 feet wide by 200 feet long, the bottom being 3 feet below low-water level; second, another basin 40 feet wide and 160 feet long, receiving water from the first, through a sluice; third, an oval tunnel 6 feet high and 300 feet long; fourth, a well 10 feet in diameter and 39 feet deep, serving as a pump-well. From this the water was



R = Roxborough works.
K = Roxborough reservoir.
B = Belmont works.
P = Schuylkill works.
F = Fairmount works and reservoir.

E = Delaware works.
N = Frankford works.
A = Mount Airy reservoir, neat Chestnut Hills works.
L = Belmont reservoir.
H = East Park reservoir.

S = Schuylkill reservoir.
G = Corinthian Avenue reservoir.
D = Delaware reservoir.
E = Frankford reservoir.

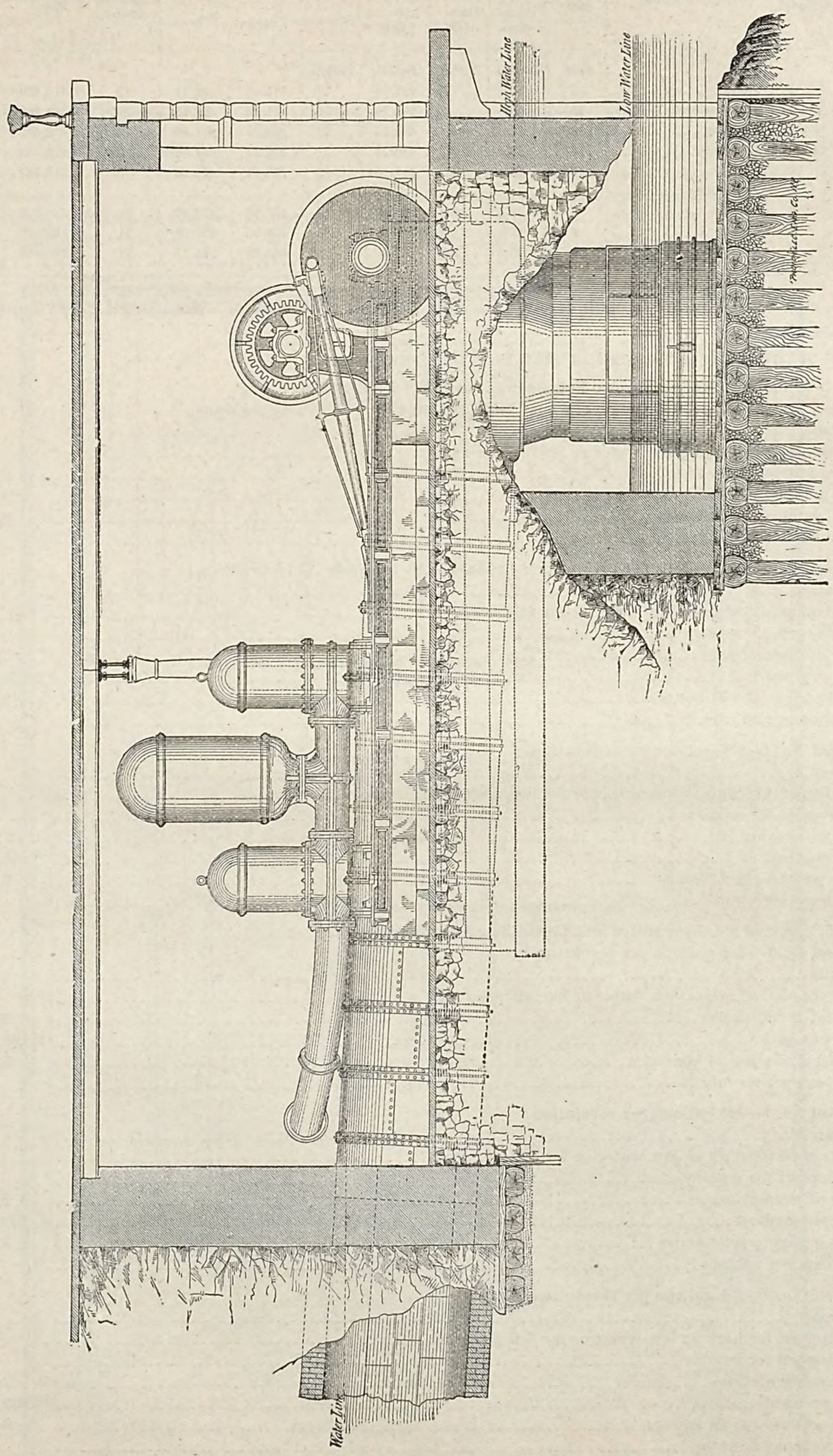
MAP OF THE PHILADELPHIA WATER-WORKS.

pumped up into two wooden tanks of a capacity of 20,800 gallons, situated in Centre square, from whence bored wooden logs distributed it. These pumping-engines have since been removed. In 1812 works were built at Fairmount, pumping into a reservoir located 102 feet above the river and having a capacity of 3,250,000 gallons. In 1818 water-power was proposed at Fairmount, and put in operation in 1822. A dam, from 17 to 18 feet wide, was built, filled with stones obliquely across the river, of a total length of 1,600 feet, giving a head of water of 13 feet; cost, $150,000. It was rebuilt in 1843; and in 1865, 450 feet of crib were placed in front of its highest part. In 1872 a new dam was built in front, the space between them being filled with concrete. At this station there are used at present seven Geyelin turbine wheels and one breast-wheel, arranged as shown in the cut on page 125. There are now eight pumping-stations, known as the Schuylkill, the Belmont, the Delaware, the Roxborough, the Auxiliary Roxborough, the Chestnut Hill, the Frankford, and the Fairmount pumping-stations. They will be described separately.

642

THE FAIRMOUNT WORKS.

The sizes and details of the wheels used at this station are given in the table on page 128.



Wheels and pumps at the Fairmount works.

No. of wheel.	Kind of wheel.	Diameter.	PUMP.				GALLONS CAPACITY.		Strokes per minute.	Gallons per day.
			Diameter.	Diameter.	Area of pump.	Stroke.	Pump.	Wheel.		
		Feet.	*Inches.*	*Inches.*	*Inches.*	*Inches.*				
1	Turbine	7	16	.....	201.06	72	121.40	122.11	12	2,110,060
2	Breast (width, 15 feet)	15	16	.....	201.06	54	91.75	91.75	14½	1,387,260
3	Turbine	10 3/12	22	22	380.13	72	230.84	461.68	8	5,318,553
4	do	10 3/12	22	22	380.13	72	230.84	461.68	8	5,318,553
5	do	10 3/12	22	22	380.13	72	230.84	461.68	8	5,318,553
6	(Removed)	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	Turbine	9	18 7/16	18⅜	266.08	72	161.95	323.90	11	5,130,576
8	do	9	18 5/16	18½	266.08	72	161.95	323.90	11	5,130,576
9	do	9	18 9/16	18⅜	267.90	72	163.09	326.18	11	5,166,690

Pumps 3, 4, and 5 are similar to each other, and Nos. 7, 8, and 9 are alike. Nos. 1 and 2 have one pump-cylinder each. The others have two each.

An account of the work performed in 1879 is given below:

Wheels Nos. 1, 3, and 4 deliver water into Fairmount reservoir. Lift, 90 feet.

Wheel No. 1—122 gallons per revolution; buckets 13 inches wide, 10 inches deep:

Hours run	3,158
Hours stopped for high or low water or for full reservoir	5,602
Number of revolutions	2,207,625
Gallons pumped	269,330,250
Average gallons per 24 hours	2,046,840
Revolutions per minute	11:6

Wheel No. 3—461 gallons per revolution; buckets 15 inches wide, 17 inches deep:

Hours run	6,568
Hours stopped for high or low water or for full reservoir	2,096
Hours stopped for repairs	96
Number of revolutions	3,770,795
Gallons pumped	1,738,336,495
Average gallons per 24 hours	6,352,008
Revolutions per minute	9.5

Wheel No. 4—461 gallons per revolution:

Hours run	4,146
Hours stopped for high or low water or for full reservoir	1,735
Hours stopped for repairs	2,879
Number of revolutions	2,922,693
Gallons pumped	1,346,361,473
Average gallons per 24 hours	7,793,688
Revolutions per minute	11.7

Wheels Nos. 5, 7, 8, and 9 deliver water into Corinthian Avenue reservoir.

Wheel No. 5—461 gallons per revolution:

Hours run	5,291
Hours stopped for high or low water or for full reservoir	3,469
Number of revolutions	2,809,570
Gallons pumped	1,295,211,870
Average gallons per 24 hours	5,875,070
Revolutions per minute	8.8

Wheel No. 7—325 gallons per revolution:

Hours run	3,536
Hours stopped for high or low water or for full reservoir	3,832
Hours stopped for repairs	1,392
Number of revolutions	2,306,292
Gallons pumped	749,544,900
Average gallons per 24 hours	5,087,400
Revolutions per minute	10.8

Wheel No. 8—325 gallons per revolution:

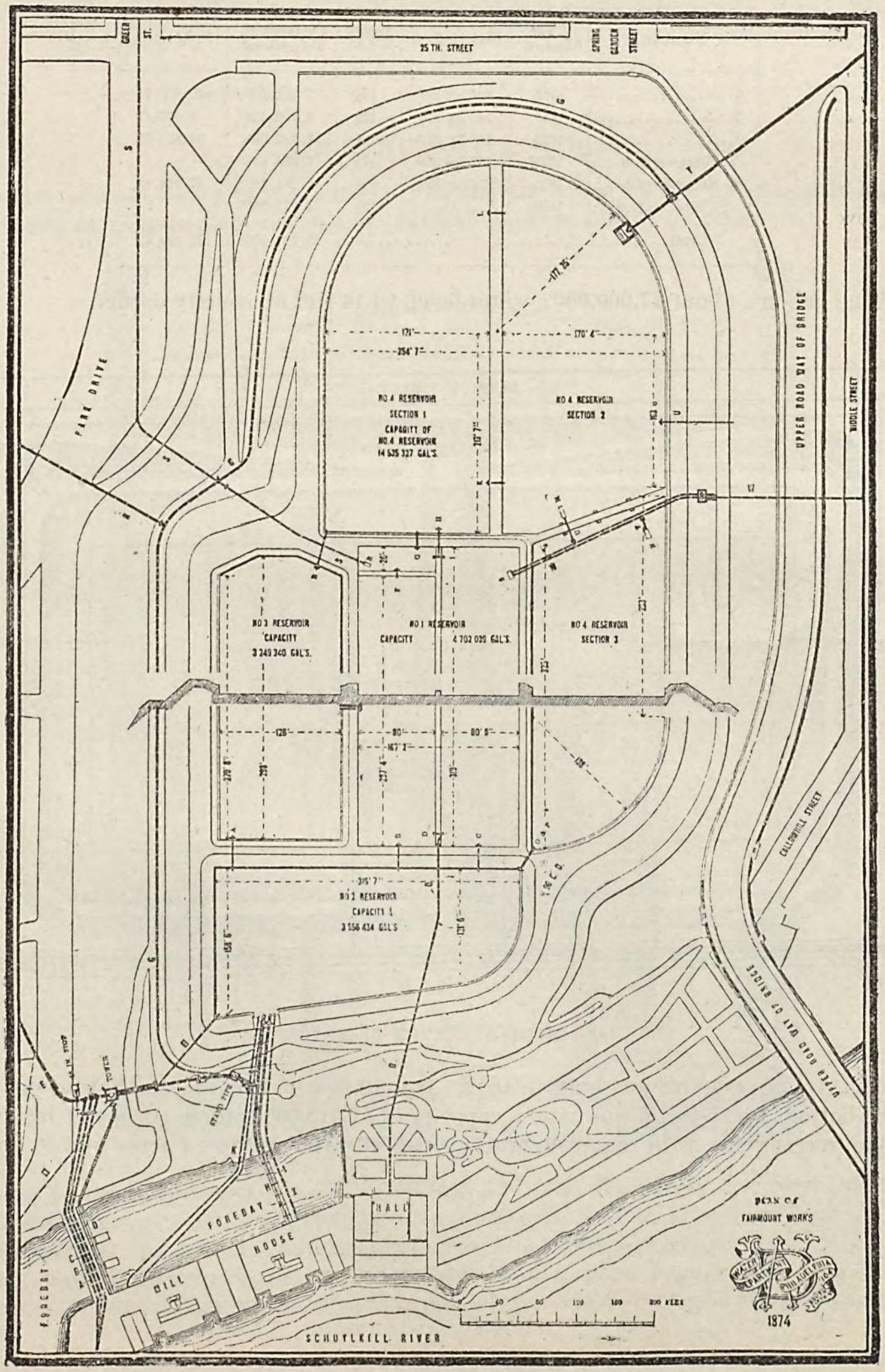
Hours run	4,358
Hours stopped for high or low water or for full reservoir	2,938
Hours stopped for repairs	1,464
Number of revolutions	2,861,458
Gallons pumped	929,973,850
Average gallons per 24 hours	5,121,456
Revolutions per minute	10.9

Wheel No. 9—325 gallons per revolution:

Hours run	4,462
Hours stopped for high or low water or for full reservoir	4,298
Number of revolutions	2,921,842
Gallons pumped	949,598,650
Average gallons per 24 hours	5,107,656
Revolutions per minute	10.9

Summary:

Total number of revolutions	19,800,275
Total number of gallons	7,278,357,488
Average number of gallons per day	37,384,118
Total number of hours	61,320
Total hours run	31,519
Total hours stopped for high or low water or for full reservoir	23,970
Total hours stopped for repairs	5,831
Percentage	0.52, 0.39, 0.09



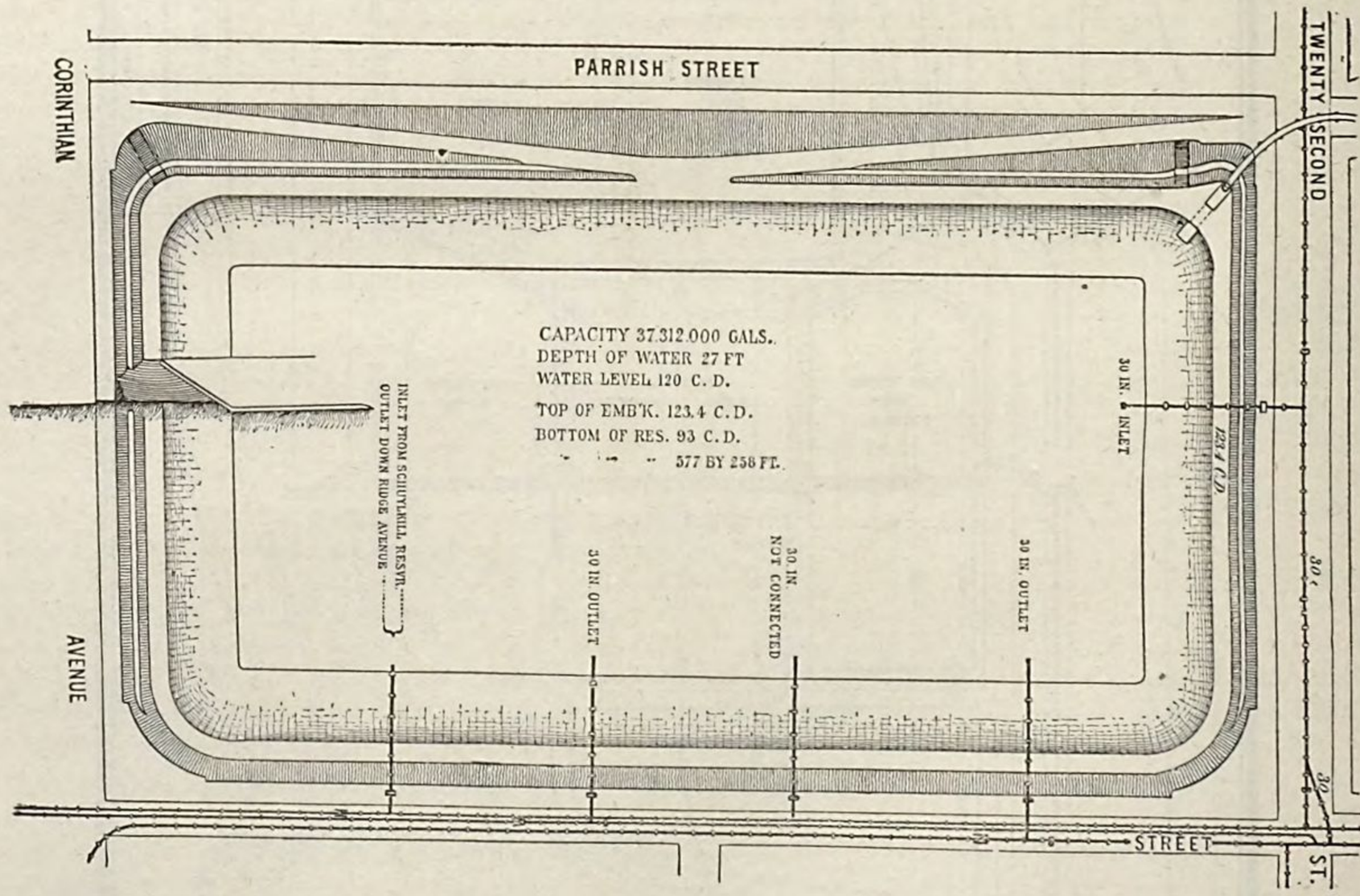
No. 2 can be run only 18 hours per day during high water. From the river the water is pumped through mains of cast iron—the lengths and diameters of which are given below—into two reservoirs. As the quantity of water supplying the turbines was insufficient during a portion of the year, it was found necessary to erect a Worthington engine, which has since been removed to the Frankford works. The details are, however, as follows: It has two double-acting plungers, 16 inches diameter by 24 inches stroke, with an actual capacity of 78.5 gallons per revolution, and running at a velocity of twenty revolutions per minute. Its capacity is 2,500,000 gallons per day. It is operated by one return-flue marine boiler.

A stand-pipe, 71 feet high by 4 feet diameter, is connected with the Fairmount system, the top being 15 feet above high water in the Fairmount reservoir. It has one inlet and two outlets; is of wrought iron, surrounded with brick at base and frame at the top. It is used with the Corinthian Avenue reservoir, and is located about 225 feet from the pumps. A 30-inch main 3,747 feet long connects it with the reservoir.

The Fairmount reservoirs shown in plan on the map on page 129 contain an average of 27,000,000 gallons. The sizes, capacity, and cost may be seen from the annexed statement:

Number.	When finished.	Size in feet.	Depth in feet.	Capacity in ale gallons.	Cost.
1	1815	167 by 317	12¼	3,917,659	$32,508 52
2	1821	140 by 316	12¼	3,296,434	9,579 47
3	1827	160 by 317	12¼	2,707,295	24,521 75
4 First section	1835	136 by 350	12¼	3,658,016	67,214 68
4 Second section	1835	358 by 392	12¼	4,381,322	
4 Third section	1836	.....	12¼	4,071,250	
Total				22,031,976	133,824 42

Capacity in wine gallons, about 27,000,000; water-level, 94.14 feet above city datum.



CORINTHIAN AVENUE RESERVOIR.

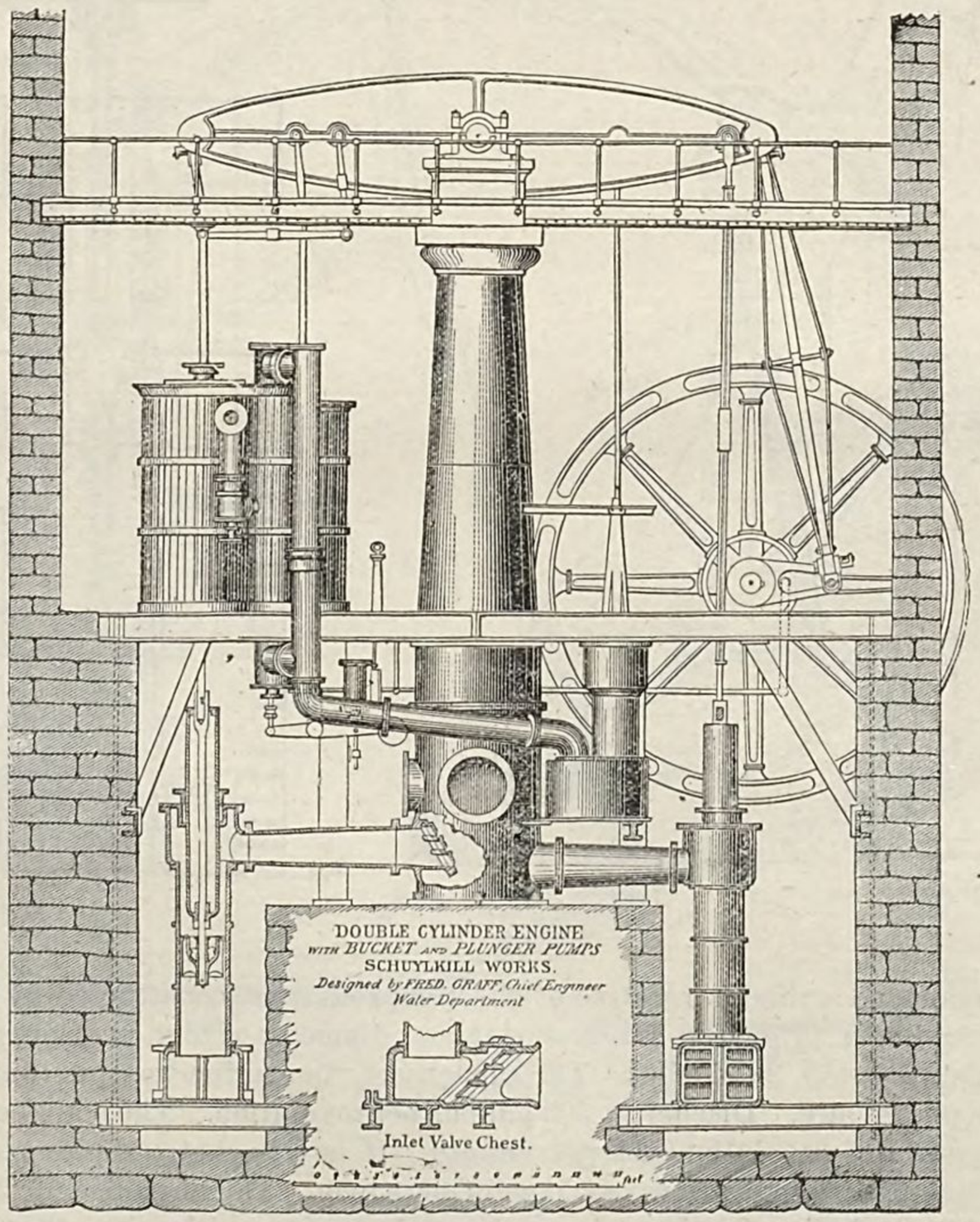
The Corinthian Avenue reservoir was built in 1852. It is 16 feet higher than the Fairmount, and measures 258 by 577 feet on the bottom by 27 feet deep, with a capacity of 37,312,000 gallons; slope of inside face, 1½ to 1; of outer, 1½ to 1; plan, rectangular, with rounded corners; area of water-surface, 4 acres and 50 square rods; width of banks, 12 feet.

The cost of the reservoir was $46,030. From it a main, 30 inches diameter, passes to Delaware reservoir, a distance of 14,000 feet. There are four 30-inch outlets, one of which is not in use. The following table gives details of the Fairmount wheels at the pumping-station:

Style of wheels and engines.	PUMPING-MAINS.						Reservoir's capacity (gallons).
	Diameter.	Length.	Diameter.	Length.	Diameter.	Length.	
	Inches.	*Feet.*	*Inches.*	*Feet.*	*Inches.*	*Feet.*	
Worthington engine	12	585	.....	.....	.....	.....	Fairmount, 26,996,636.
No. 1, Jonval wheel	16	433	.....	.....			
No. 2, breast-wheel	16	183	.....	.....			
No. 3, Jonval wheel	36	240	.....	.....			
No. 4, Jonval wheel	36	320	.....	.....			
No. 5, Jonval wheel	36	293	.....	.....	.....	.....	
No. 7, Jonval wheel	20	46	30	273	30	3,747	Corinthian, 37,312,000.
No. 8, Jonval wheel	20	46	30	304	48	3,576	
No. 9, Jonval wheel	20	46	30	338	.....	.....	

THE SCHUYLKILL WORKS.

These works, the position of which can be seen from the plan on page 126, and formerly known as the Spring Garden works, consist of, (1) pumping-station and engines; (2) force-mains; (3) reservoir.



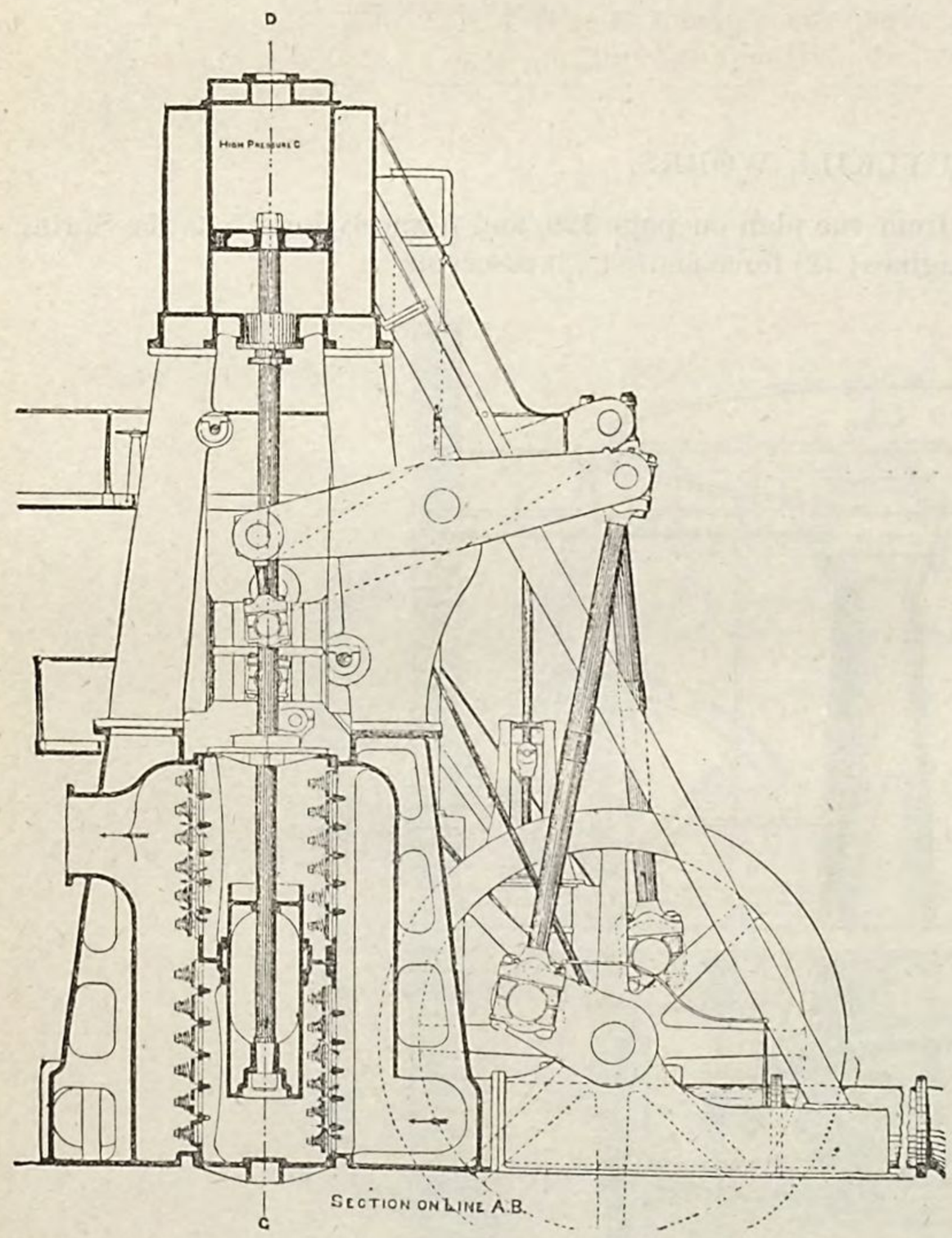
The fore-bay of the engine-house is 450 by 60 feet, and conduits convey the water into the different pump-wells. Of the seven engines which have been used in these works three have been worn out and removed after twenty-five years' service. At present there remain four by the following makers:

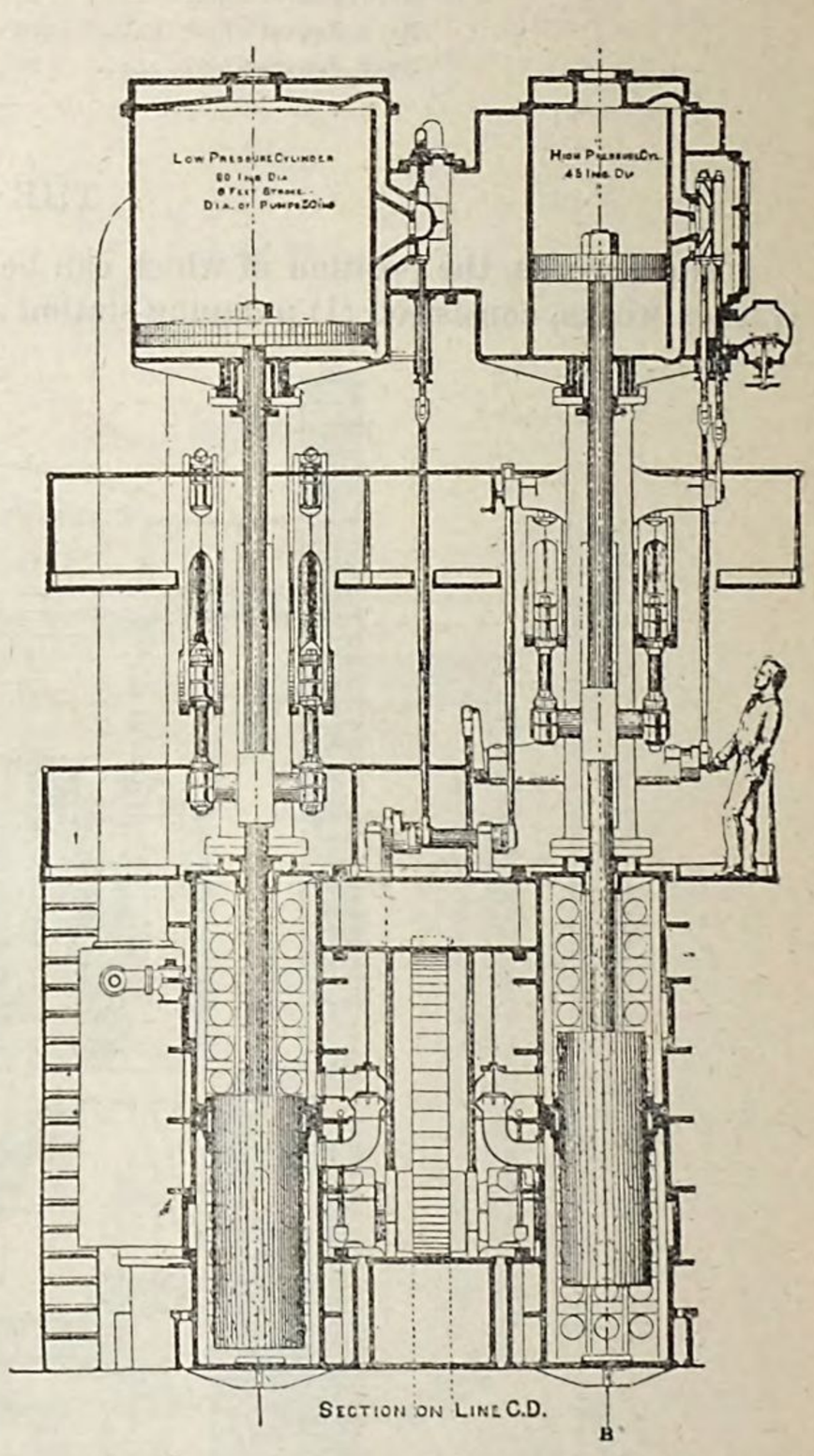
Engine No. 4, by I. P. Morris & Co., of Philadelphia, is a Cornish engine with single-acting plunger-pump operated by a beam. The plunger is weighted, and beneath it is a double-beat inlet-valve of cast iron on composition

seats. The discharge-valve is treble-beat. The diameter of steam-cylinder is 60 inches, and stroke 120 inches; pump-cylinder, 30 inches diameter and 120 inches stroke; duty averaged at 50,000,000 foot-pounds, and has reached as high as 58,000,000; air-pump, 22 inches by 5 feet stroke, with a jet-condenser; capacity, about 5,000,000 gallons. Four plain cylinder boilers with two mud-drums, each 4 feet 3 inches diameter of shell by 32 feet long, furnish the requisite steam. The mud-drums are 26 inches diameter by 23 feet long.

Engine No. 5 is a side-lever Cornish, of a capacity of 7,500,000 gallons, operating against a lift of 120 feet, including friction, and of 193 horse-power. It has one single-acting plunger, with pump-cylinder 36 inches diameter; stroke, 120 inches. The diameter of steam-cylinder is 72 inches, and stroke 10 feet. Connected with this is an air-pump 26 inches in diameter by 4 feet stroke. This engine was built in 1869 by Merrick & Sons. During 1879 it pumped 440 hours, at an average of ten revolutions per minute. The theoretical discharge is 528.9 gallons per revolution, forced into the Schuylkill reservoir. It has one inlet- and one outlet-valve in the pump-cylinder.

Steam is supplied by six cylinder boilers, 4 feet 6 inches diameter by 30 feet long, with two mud-drums, each 28 inches diameter by 22 feet long. The duty averaged as high as 50,000,000 foot-pounds in 1879. The pump-valves are of double-beat Cornish pattern.





Engine No. 6 is a compound cylinder rotative of the Simpson type, constructed by Henry G. Morris in 1872. Diameter of low-pressure cylinder, 57 inches; stroke, 96 inches; diameter of high-pressure cylinder, 36 inches, stroke 61 inches; diameter of pump piston, 28½ inches. The capacity of the engine was guaranteed at 10,000,000 gallons per day at 14 revolutions per minute. Discharge, 500 gallons per revolution. The actual capacity is about 8,000,000 gallons per day, and number of revolutions 11 per minute. It is a bucket-and plunger pump, with two double-acting plungers and rubber-disk pump-valves, with a lift of 1 inch. The engine is of 294 horse-power, pumping against a height of 170 feet, including friction. It can be made to pump either into the Schuylkill or into the East Park reservoir. It was run 4,900½ hours in 1879. The duty in 1879 averaged about 56,900,000 foot-pounds. It derives steam from a battery of five multitubular boilers, 6 feet in diameter by 15 feet long, containing seventy-five 4-inch tubes each. The air-pump is 22 inches diameter by 4 feet stroke. A jet-condenser used is 4 feet 8 inches by 3 feet 8 inches.

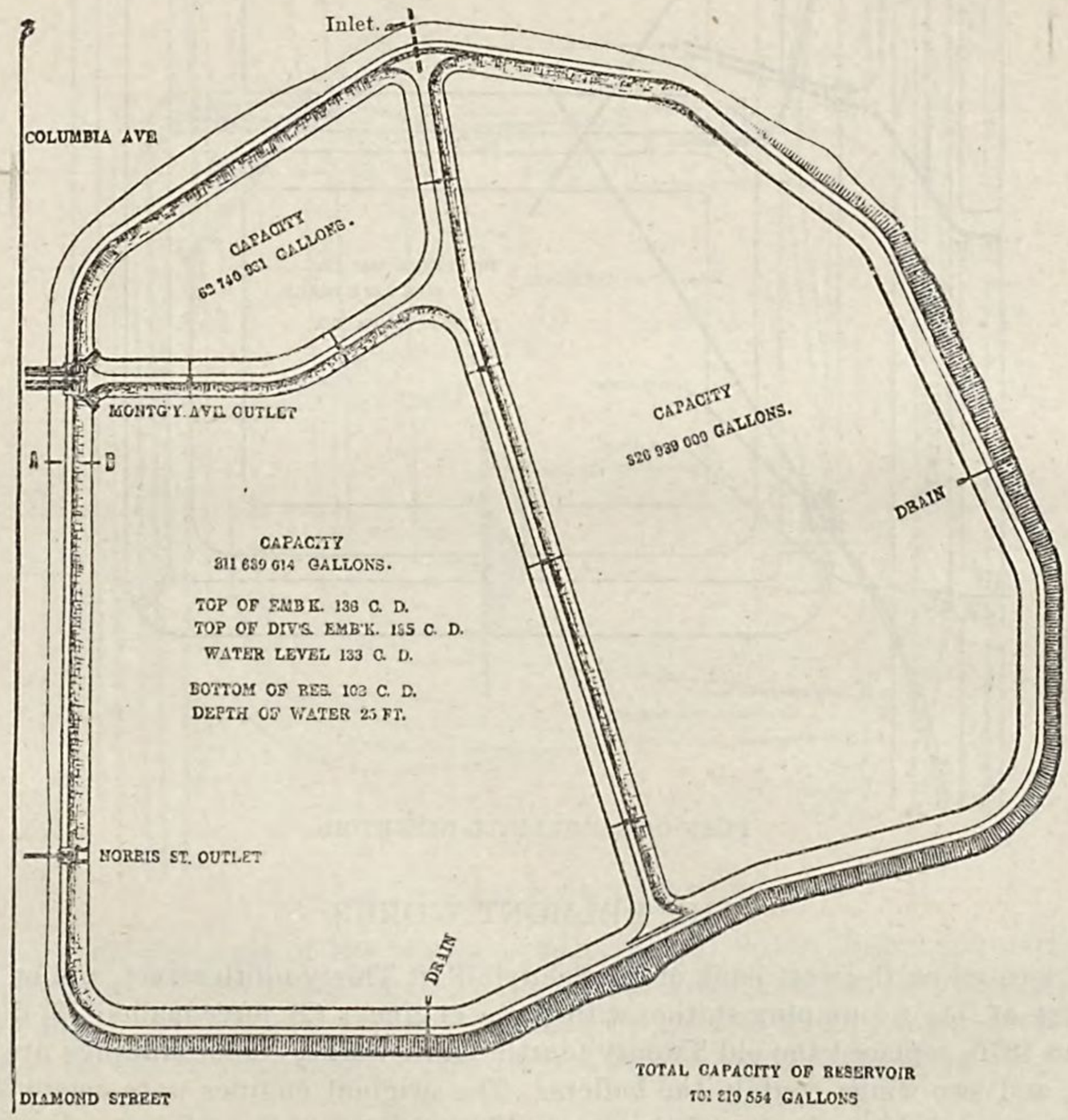
Engine No. 7 is an upright, rotative, independent, compound engine. The cylinders are placed side by side, with a double-acting plunger-pump beneath each. The fly-wheel is at the back, worked by beams obtaining motion from a cross-head between cylinder and pump. The cylinders are 80 inches and 45 inches, respectively, in diameter, by 6 feet stroke. It was constructed to pump into the East Park reservoir, a lift of 130 feet, and the duty was guaranteed at 75,000,000 foot-pounds with the boilers evaporating 9½ pounds of water. The duty-trial showed a capacity of 75,065,689 foot-pounds pumped to a height of 121.96 feet, the boilers having an evaporative power of 8.62 pounds to 1 pound of coal.

The theoretical capacity of the pump is 850 gallons per revolution. The engine in 1879 pumped 2,319,436,660 gallons with a consumption of 1,809⅓ tons of coal, running 3,638 hours, with a lift of 120 feet, including friction. It was built by W. Cramp & Sons, Philadelphia, in 1876. There were no boilers specially provided for the engine, but steam is supplied by those already in use with the other engines at the station. All the engines are seldom run at the same time. In addition to those already mentioned there are two hog-nose tubular boilers, 5 feet diameter by 17 feet 9 inches long, containing eighty-three 3-inch tubes in each, 12 feet long, and one drum, 30 inches by 12 feet, to each boiler.

Another battery of five tubular boilers is now being erected, similar to those described under engine No. 6.

From the Schuylkill station the water is to be pumped through one 48-inch main, 2,100 feet long, into the East Park reservoir, but is at present pumped through two 36-inch, one 20 inch, and two 16-inch mains into the Schuylkill reservoir, a length of 3,300 feet each.

The position of the East Park reservoir is shown on page 126, and its plan in the accompaning drawing. It has never been completed. It is intended to contain 750,000,000 gallons at a depth of 25 feet.

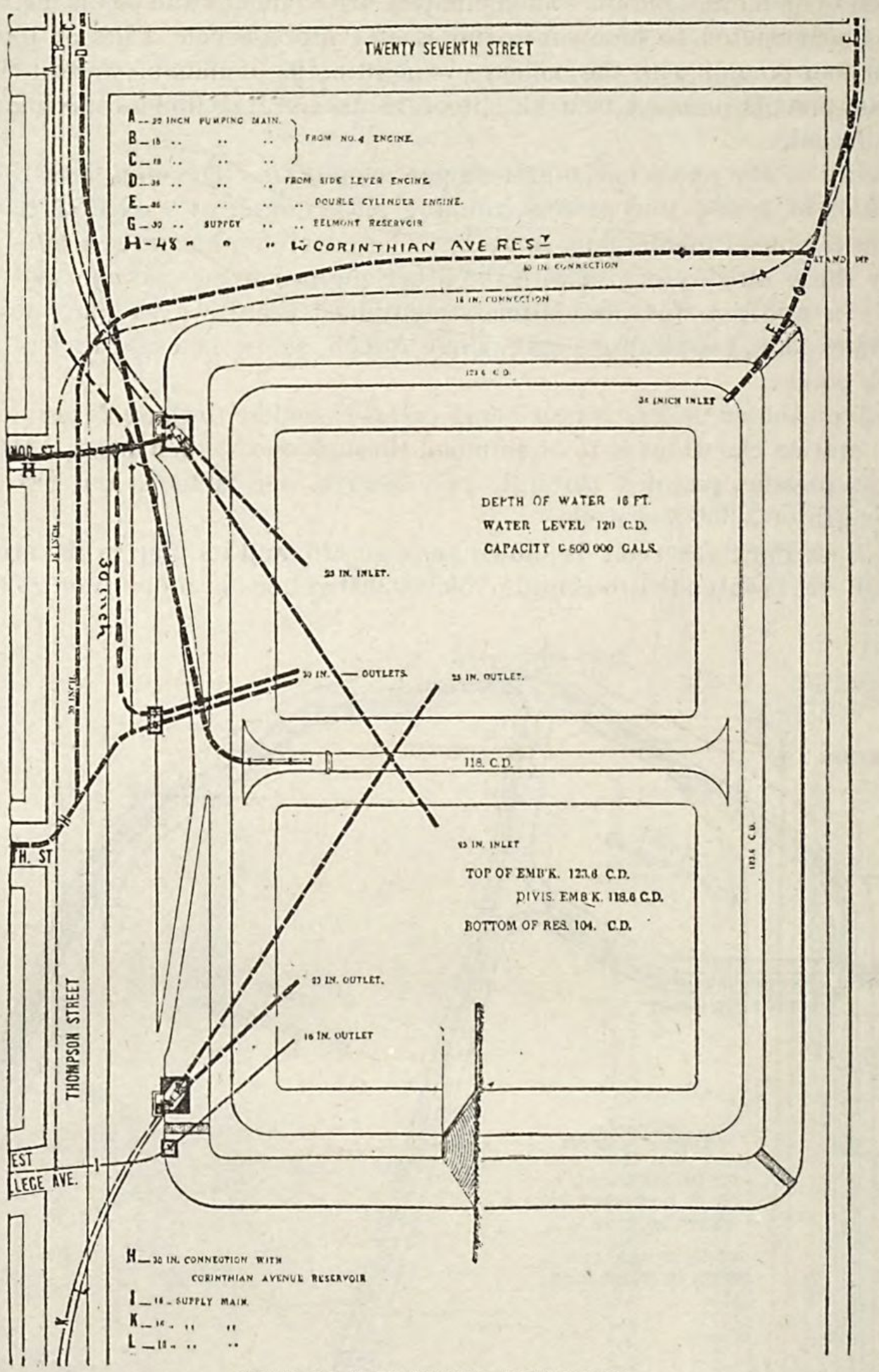


PLAN OF EAST PARK RESERVOIR.

In close proximity to the engine-house is a stand-pipe of wrought-iron, 6 feet in diameter at bottom and tapering to 3 feet 6 inches at top, with an octagonal stone base and ornamental cap and cornice. Height, 137 feet. There are three 30-inch inlets and one 45-inch outlet, the former being directly connected with the engines.

Schuylkill reservoir, sometimes known as Spring Garden reservoir, is located on the corner of Twenty-seventh and Master streets, 3,250 feet on the line of the main from the pumping-station, at a height of 120 feet above city datum, and has a capacity of 9,800,000 gallons, with an area of water-surface of 2 acres and 108 square rods. It is formed of earth embankments, puddle-faced, and riprapped with brick, and contains a division-wall built within 4 feet of the top, which divides it into two basins, one of which is the receiving and the other the distributing

section, the water flowing over it like a weir at high water. It is 16 feet deep when full, and is 510 feet long by 368 feet wide. Width of banks at top, 13 feet; slope, 1½ to 1. There are three supply-mains, each 16 inches in diameter.



PLAN OF SCHUYLKILL RESERVOIR.

THE BELMONT WORKS.

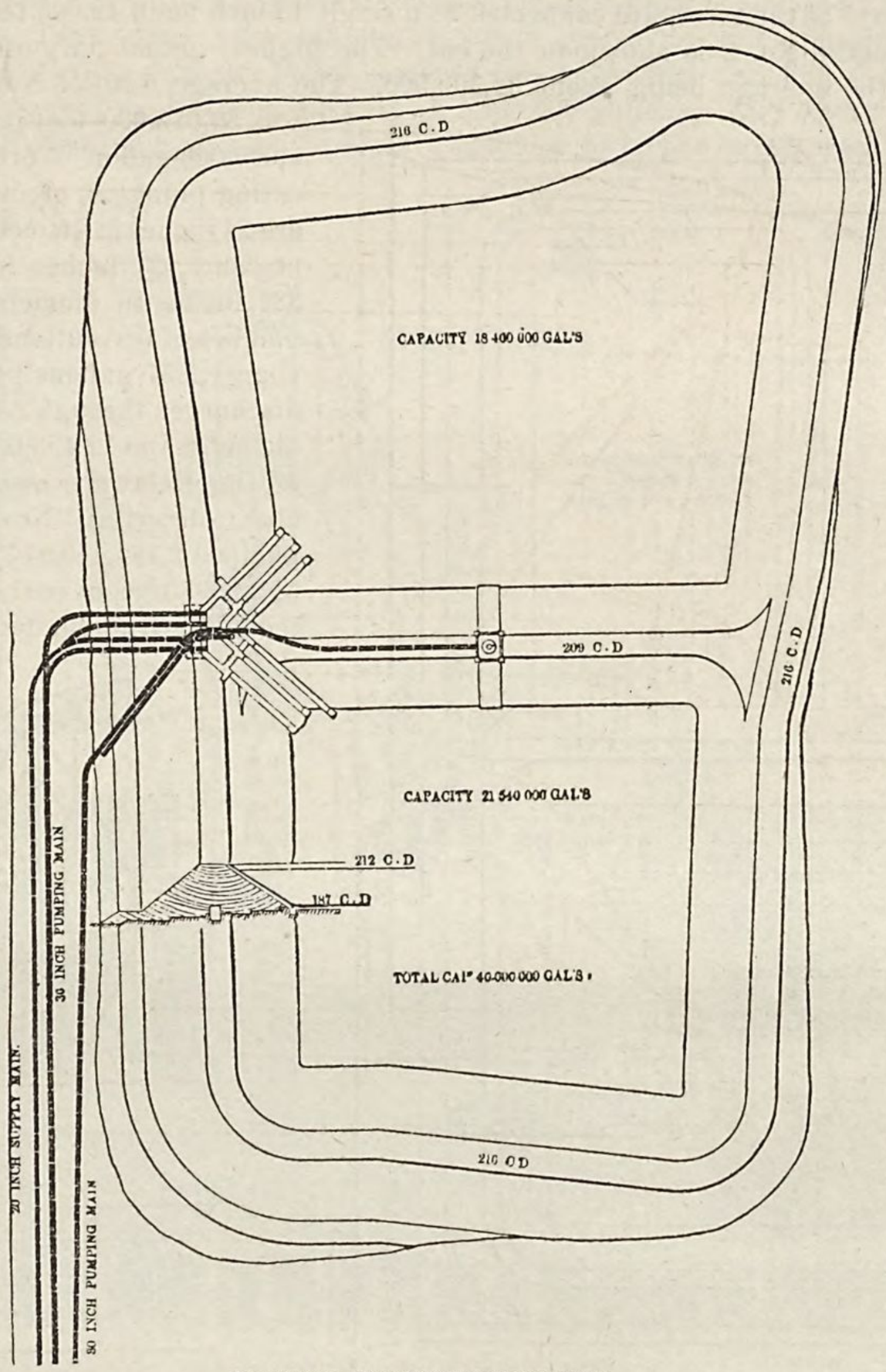
These works are located on the west bank of the Schuylkill at Thirty-ninth street, and on a line with Columbia avenue. They consist of, (1) a pumping-station with three engines; (2) force-mains; (3) distributing reservoirs. The present works, in 1870, replaced the old Twenty-fourth Ward works. The buildings are of stone, the engine-house being circular, and two wings contain the boilers. The original engines were removed in 1870, and three Worthington engines were substituted; two of these are alike, and are of the following dimensions: Low-pressure cylinder, 50¼ inches in diameter; high-pressure cylinder, 29 inches in diameter; pump-plunger, 22½ inches in diameter; stroke, 4 feet; stroke of air-pumps, 2 feet. They are each of 5,000,000 gallons capacity, and at a test of engine No. 2 in 1872 a duty of 54,417,000 foot-pounds was obtained.

Engine No. 3, of 8,000,000 capacity, has a low-pressure cylinder 58¼ inches in diameter, high-pressure cylinder 33¾ inches in diameter, pump-plungers 28 inches in diameter, stroke 4 feet; connected with it are four air-pumps, two of which are each 23¾ inches in diameter by 23 inches stroke, and two others each 29¾ inches in diameter by 23 inches stroke.

For engines Nos. 1 and 2 there are six cylinder boilers, each 42 inches in diameter; 30 feet long, and having one drum 30 inches by 22 feet. For engine No. 3 there are eight cylinder boilers, each 54 inches in diameter, 30

feet long, with two mud-drums each 28 inches in diameter by 22½ feet long. These engines pump against a head of 207 feet and run at an average of 12 revolutions per minute. No. 1 pumped 1,291,341,900 gallons with a consumption of 3,070.1 tons of coal during 6,022 hours. No. 2 pumped 638,127,672 gallons during 2,957¼ hours, consuming 1,481¾ tons. No. 3 pumped 2,025,493,345 gallons during 5,414½ hours, consuming 4,067½ tons of coal.

No. 1 pumps through a 30-inch main 4,400 feet long, into the Belmont reservoir. The discharge-pipes of Nos. 2 and 3 unite into one 36-inch main, 4,200 feet long, also discharging into the Belmont reservoir.



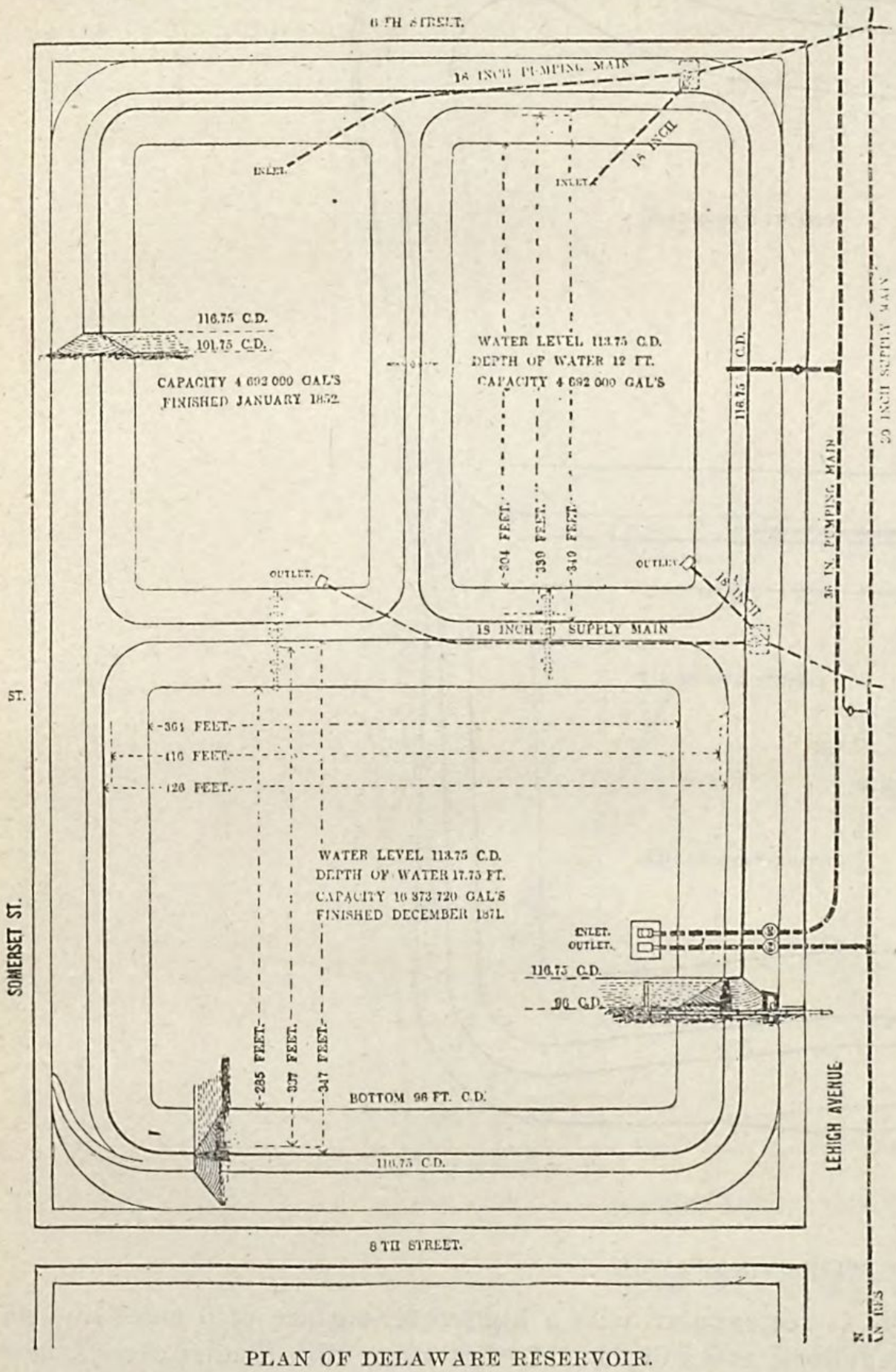
PLAN OF BELMONT RESERVOIR.

Belmont reservoir, 4,000 feet east of the works, is rectangular, with a high-water surface of 6 acres and 46 square rods, a capacity of 40,000,000 United States gallons, and a depth of 25 feet when full. High-water surface is 212 feet above city datum. The reservoir is 675 feet long by 450 feet wide; bottom area 375 feet wide by about 260 feet long in each of its two compartments. There is one 20-inch supply-main from the eastern compartment.

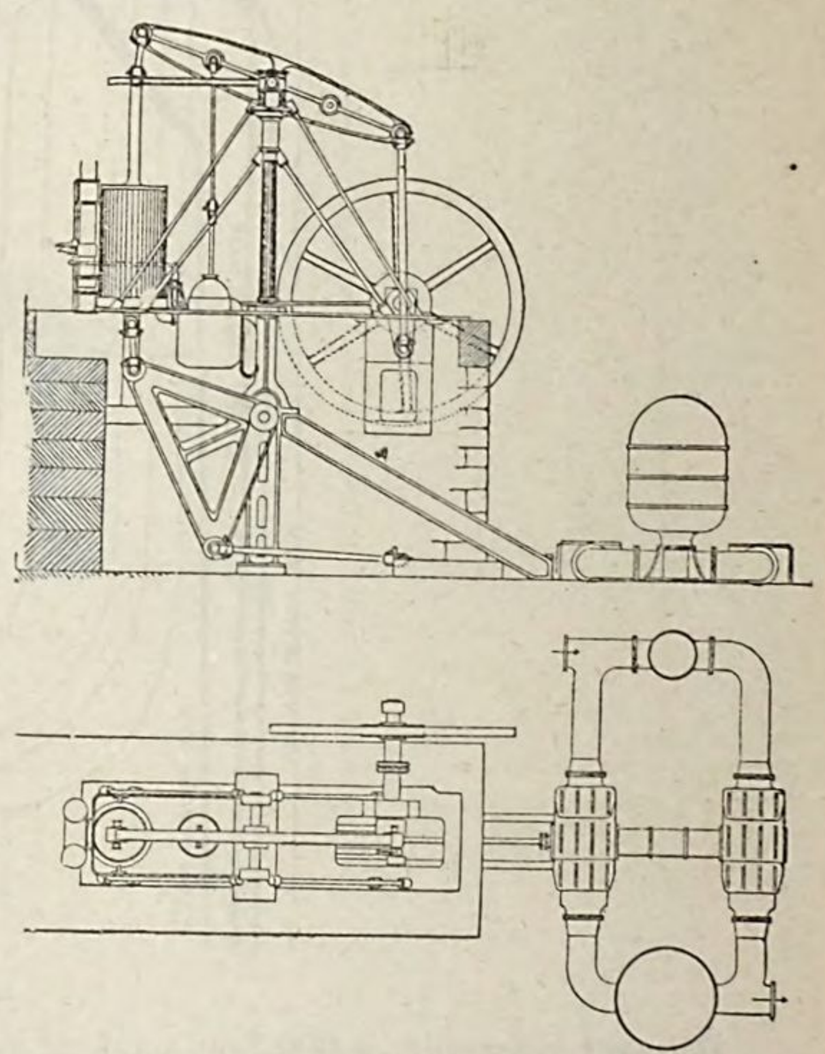
THE DELAWARE WORKS.

These works are located on the right bank of the Delaware at the foot of Otis street. The engine-and-boiler house is a brick building erected in 1851. The original cost of the works was $200,000. In the pump-house there are three engines. The first, or No. 1, is a double-acting, high-pressure, horizontal engine, operating a double-acting horizontal pump, whose piston is worked by a vertical beam 18 feet long, to the upper end of which are connected both the connecting-rod of the steam-cylinder and the connecting-rod of a fly-wheel. The diameter of the steam-cylinder is 30 inches; diameter of pump-cylinder, 18 inches; stroke, 72 inches; actual discharge, 145 gallons per revolution; capacity, 3,750,000 gallons; average number of revolutions per minute, 18. The pumps contain metallic flap-valves seated in at an angle of 45°. Engine No. 2 is a condensing beam-

engine with a vertical cylinder. One end of the beam is connected with the fly-wheel, and from the other a piston-rod passes through the steam-cylinder and is connected by a short link with a horizontal arm of a right-angled bell-crank lever, from the lower vertical arm of which the pump-rod is operated. The steam-cylinder is 42 inches in diameter; pump-cylinder, 19½ inches in diameter; stroke, 6 feet; pump, double-acting; actual capacity, 172 gallons per revolution; average number of revolutions per minute, 18; daily capacity, 4,500,000 gallons; air-pump 21 inches in diameter, 3 feet stroke. It was built by Reaney & Neafie in 1851. The pumps of engines Nos. 1 and 2, which are several feet below the level of the river, are connected to a single 18-inch main 12,000 feet long, emptying into the Delaware reservoir. Engine No. 2 is shown in the cut. The highest actual duty of engine No. 1 in 1879 was 37,000,000 foot-pounds, the average being about 34,300,000. The average duty of No. 2 during the same period was 33,675,000 foot-pounds. Engine No. 3 is a 6,000,000-gallon Worthington with two double-acting plungers, erected in 1871. The plungers are 24 inches in diameter; steam-cylinders: high-pressure, 21 inches in diameter; low-pressure, 33⅜ inches in diameter; stroke, 4 feet; average number of revolutions per minute, 12; actual discharge, 357 gallons per revolution. This engine discharges through a cast-iron main 36 inches in diameter and 12,493 feet long into the new section of the Delaware reservoir. The three engines above described, Nos. 1, 2, and 3, during 1879 pumped 2,194,470,977 gallons with a consumption of 2,980¾ tons of coal, against a head of 133 feet, including friction, during a total of 9,869 hours.



PLAN OF DELAWARE RESERVOIR.



ENGINE NO. 2, DELAWARE WORKS.

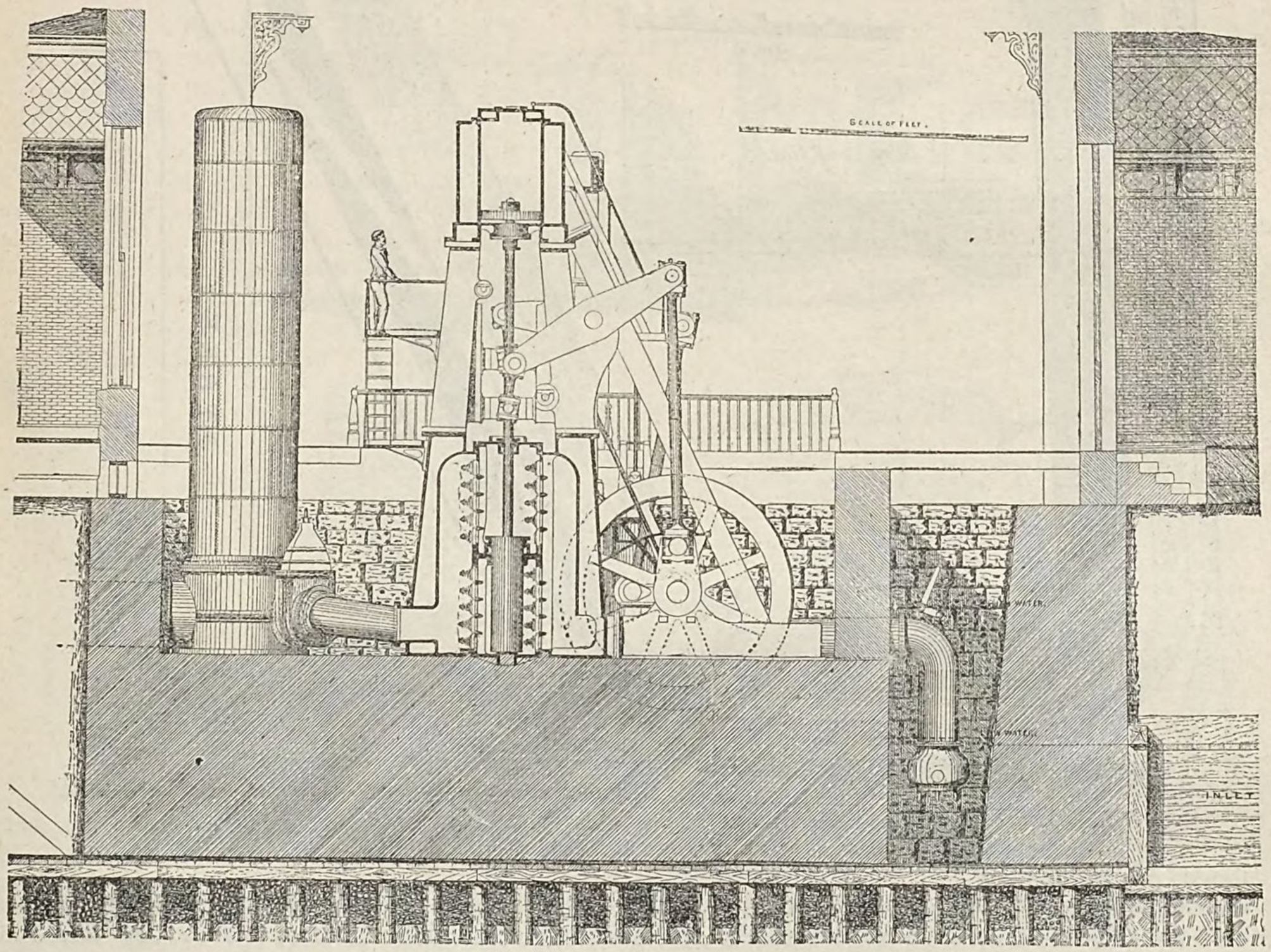
The Delaware works, to furnish steam for the above engines, contain each eight cylinder boilers 42 inches in diameter and 26 feet long, with one drum 30 inches in diameter by 16½ feet long. Another battery has five plain tubular boilers each 6 feet in diameter, 15 feet long, and each containing seventy-five 4-inch tubes. The pumps deliver their supply into a stand-pipe 5 feet in diameter by 157 feet high. It has a stone base and plain shaft. There are one 30-inch and two 18-inch inlets, one 18-inch and one 30-inch outlet extending to the Delaware reservoir.

Delaware reservoir, located at Seventh and Sumerset streets, is in three divisions, the largest one of which was built in 1871 as an addition to the small ones. It covers an area of 3.29 acres, with a depth of water of 17 feet 9 inches, and contains 16,373,718 United States gallons. It is 500 feet long by 400 feet wide at high-water surface; slope of banks 1½ to 1; each of the smaller sections is 425 feet long by 240 feet wide. The depth of water in the old sections is only 12 feet, and the combined capacity 9,800,000 gallons, making the total capacity of the Delaware reservoirs 26,173,718 gallons. The water-surface is 114 feet above city datum. The old sections are formed by

embankments puddled with clay and lined with bricks laid in cement; slope 1½ to 1. There are two 18-inch supply-mains leading from this reservoir to the distribution mains, and a 30-inch main, previously mentioned, connects it with the Corinthian Avenue reservoir.

THE FRANKFORD WORKS.

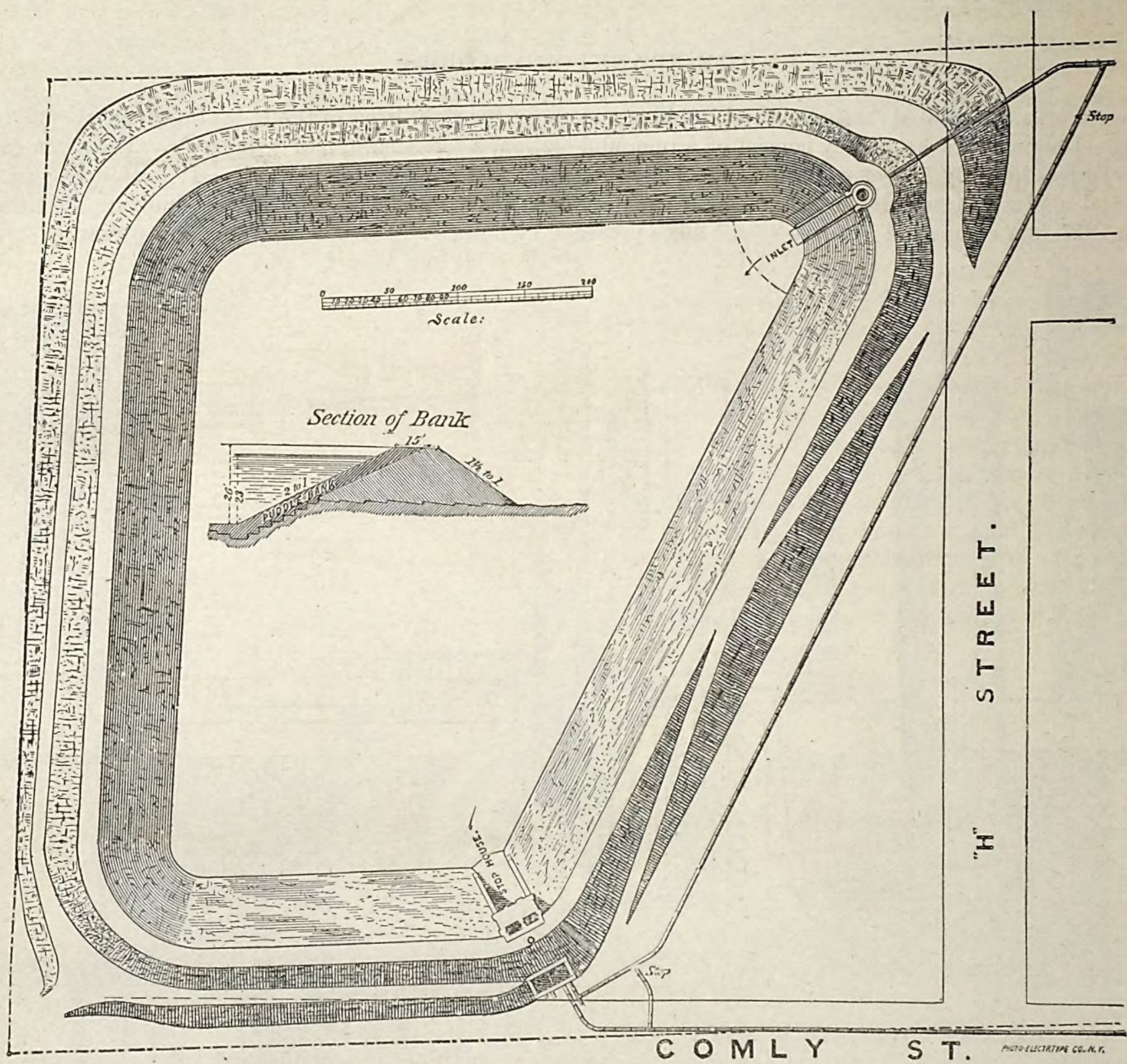
These works are located at Eugene and Robbins streets, on the right bank of the Delaware river, about 5⅓ miles above the Delaware works. They consist of a pumping-station, a force-main, and a reservoir. The main engine-house is 60 feet long by 47 feet wide, with the boiler-house 72 feet long by 40 feet wide. It contains one Cramp engine and a Worthington donkey-engine of a capacity of 2,500,000 gallons. The former, built by W. Cramp & Sons, in 1877, is a compound rotative with a high-pressure cylinder 40 inches in diameter, low-pressure 69 inches



CRAMP ENGINE—FRANKFORD WORKS.

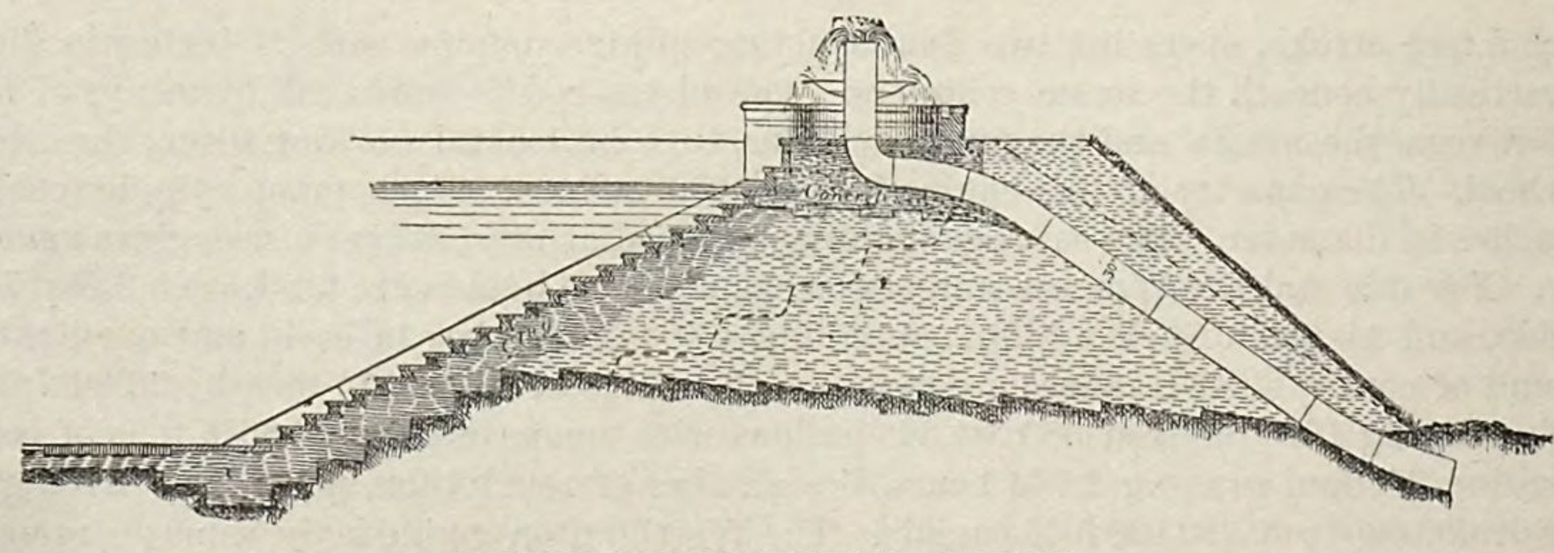
in diameter, each 5 feet stroke, operating two double-acting plunger-pumps, each 21 inches in diameter by 5 feet stroke, placed vertically beneath the steam-cylinders. The piston-rod is connected, by means of a short link, at a point midway between the steam- and the pump-cylinder, to a horizontal working-beam, the other end of which operates a fly-wheel. The capacity of this engine is 9,500,000 gallons. Each pump-cylinder contains 40 puppet-valves, each 8 inches in diameter. The average quantity pumped at present by these engines amounts to 3,500,000 gallons per day. For this and the Worthington engine four marine-boilers are used, each 9 feet 10 inches long, 9 feet 6 inches wide, and 11 feet 6 inches high, containing 130 4-inch tubes in each, and evaporating 10½ pounds of water per pound of coal. Their furnaces are two to each boiler, and 3 feet 1½ inch by 3 feet 7 inches in section. The Cramp engine during 1879 pumped 583,081,803 gallons with a consumption of 807⅓ tons of coal, against a lift of 203 feet, including friction, running 1,764 hours, the number of revolutions per minute averaging 16. Actual duty varies from 50,000,000 to 60,000,000 foot-pounds. The Worthington engine in the same year pumped 182,469,990 gallons, consuming 470½ tons of coal while running 1,874¼ hours. Duty varies from 20,000,000 to 30,000,000 foot-pounds. A view of the Cramp engine and a sectional view of the pumping-station are given in the above cut.

Frankford reservoir.—From the pumping-station the water is forced through a main 20,250 feet long and 30 inches diameter into the Frankford reservoir, 167 feet above city datum. It is trapezoidal in plan, as shown in the



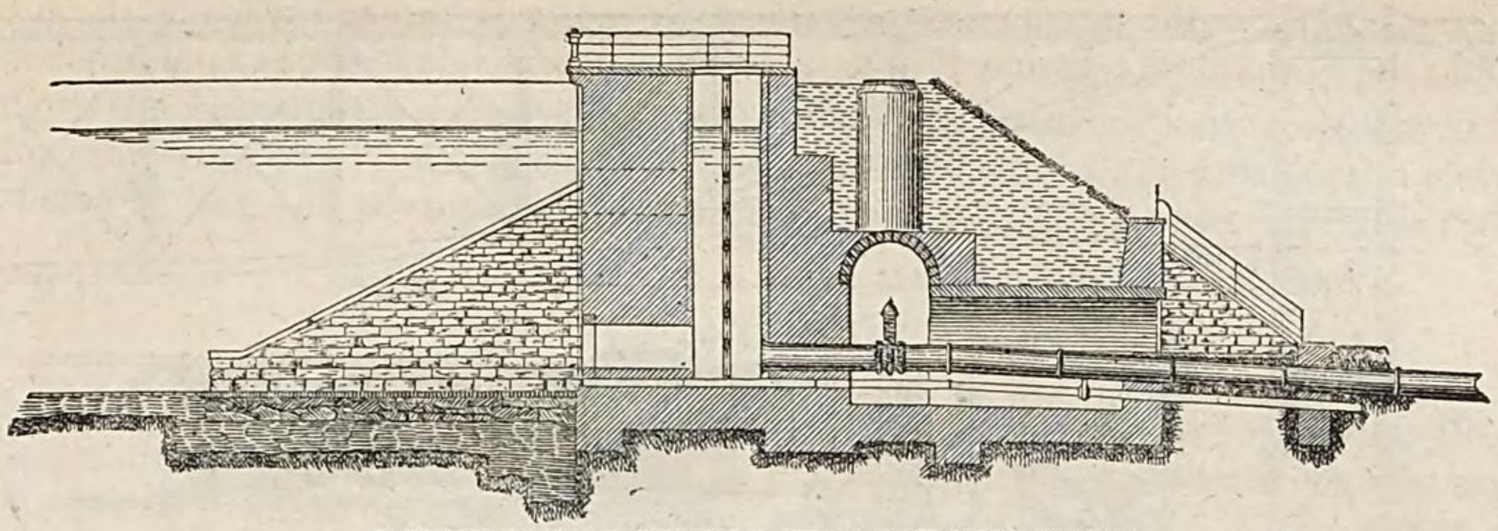
FRANKFORD RESERVOIR.

cut, with a bottom area of 166,250 square feet; water-level area, 248,250 square feet; capacity, 35,750,000 gallons; depth, 23 feet; height of banks, 3 feet above high-water level; width of banks at top, 15 feet. The force-main discharges over the eastern corner of the bank, falling over a flight of stone steps, as shown, into the reservoir.

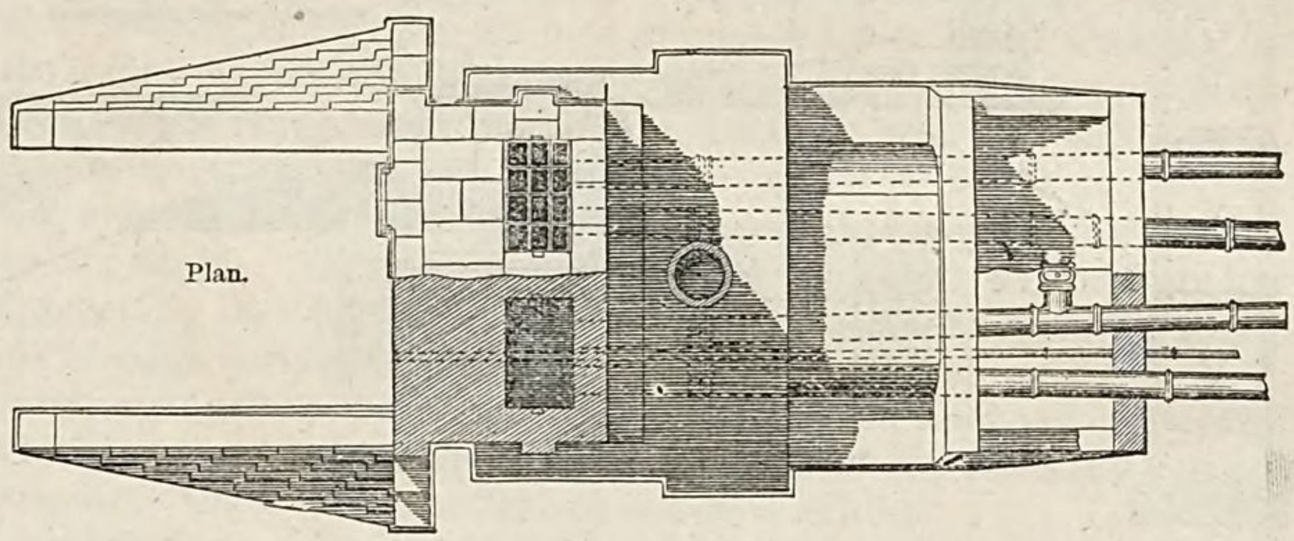


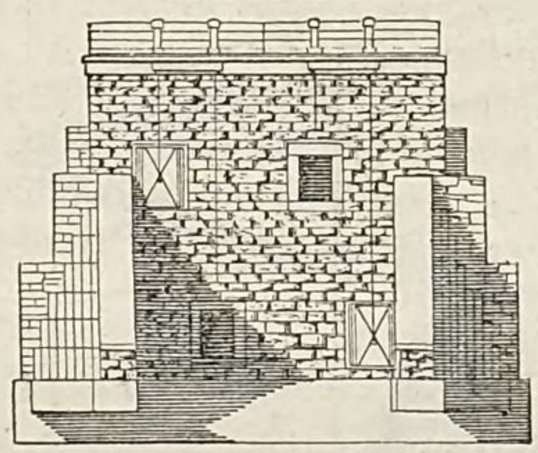
SECTION OF EMBANKMENT AT INLET.

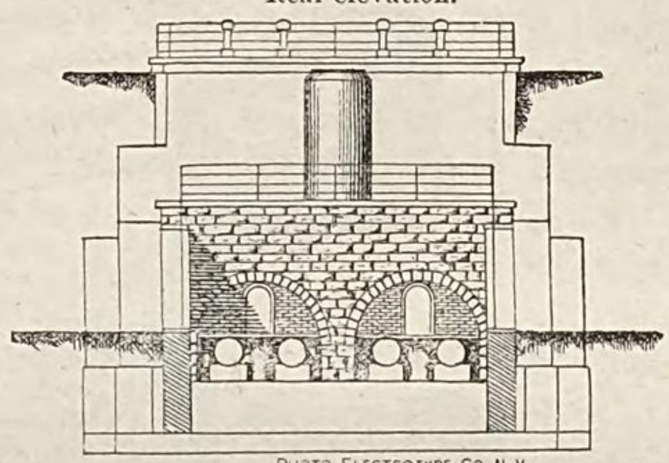
The slope of the interior face is 2 to 1; exterior, 1½ to 1. The interior is puddled 4 feet thick. Details of the gate-house are shown in the cuts on page 139. From the reservoir a single 20-inch main supplies the Frankford reservoir.



LONGITUDINAL SECTION THROUGH STOP-HOUSE.







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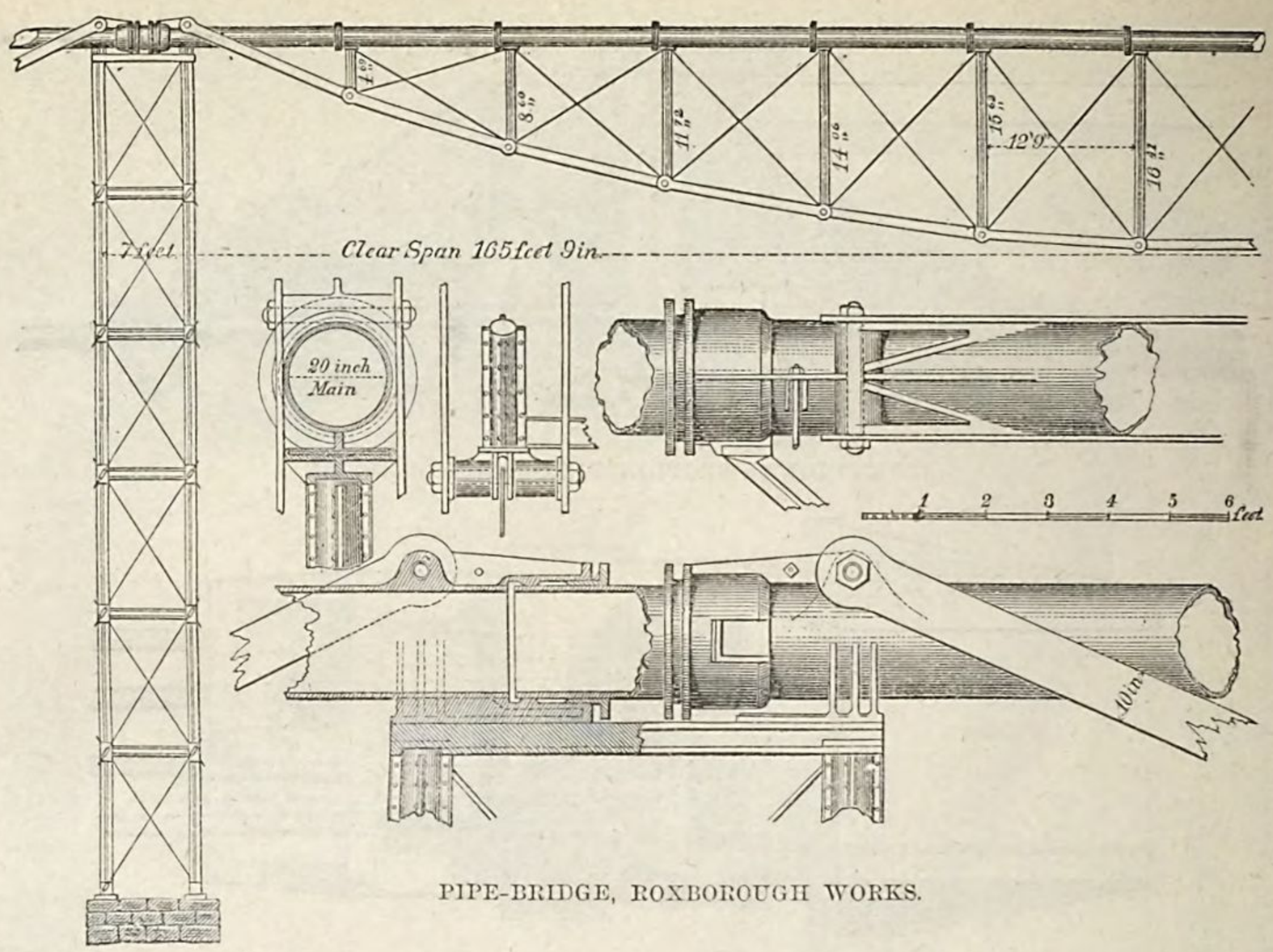
DETAILS OF GATE-HOUSE, FRANKFORD RESERVOIR.

THE ROXBOROUGH WORKS.

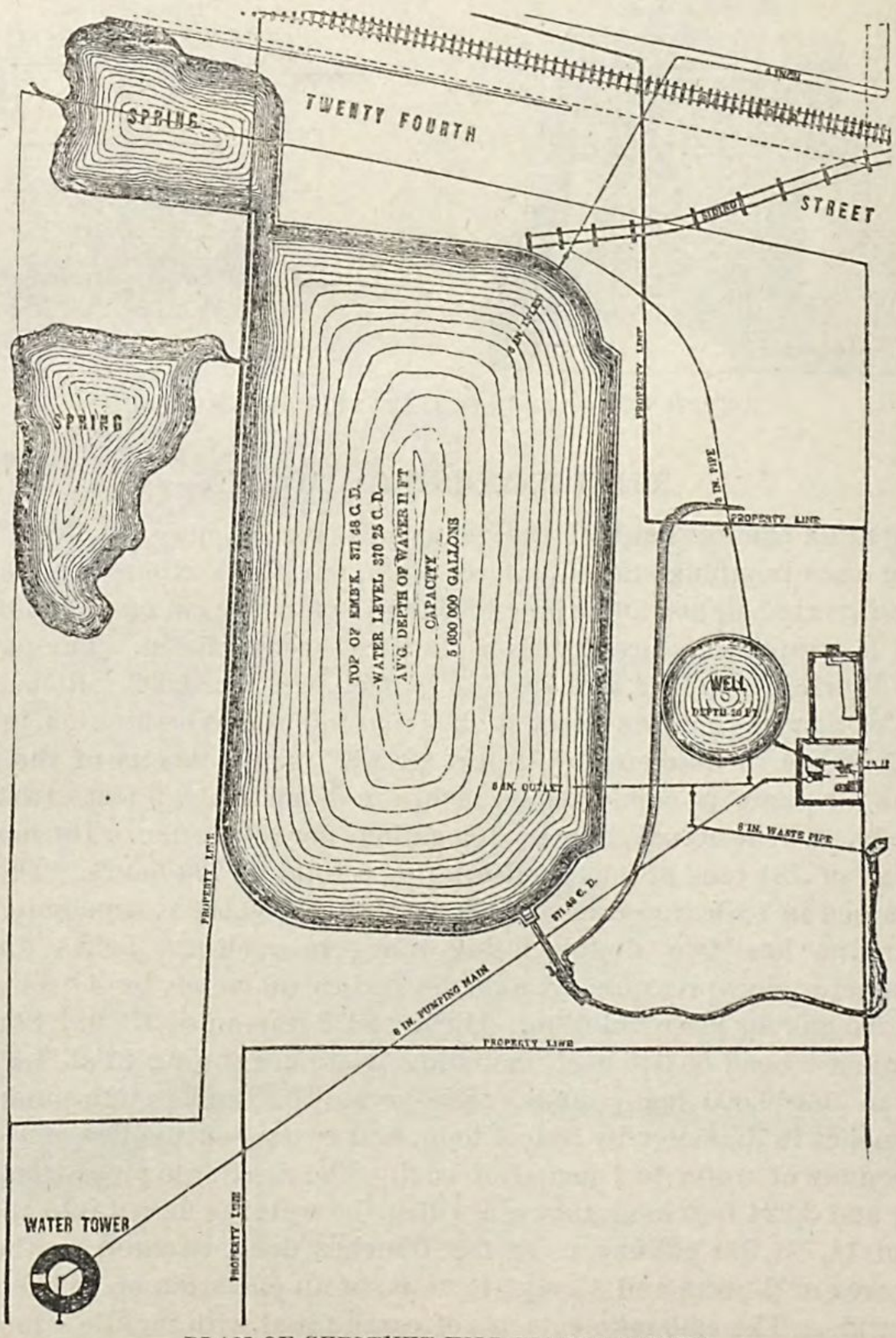
These works are located on the left bank of the Schuylkill river about 5.7 miles above the Belmont pumping-station, and consist of the main pumping-station, a force-main, and the Roxborough reservoir. By means of a line of connecting main and an inverted siphon and a pipe-bridge shown in the cut on page 140, a second reservoir, known as Mount Airy reservoir, is supplied by gravity from the Roxborough basin. The pumping-station contains two engines, a Cornish and a Worthington, the former of a capacity of 2,289,600 gallons, the latter of a capacity of 4,248,000 gallons. The Cornish engine was erected in 1869 and the Worthington in 1872. The former has one single-acting plunger 20¼ inches in diameter by 10 feet stroke. The diameter of the steam-cylinder is 72 inches, stroke 10 feet, to which an air-pump is connected 36 inches in diameter by 5 feet stroke. The average number of revolutions per minute is 10, and the actual capacity 159 gallons per revolution. During 1879 it pumped 161,442,240 gallons, with a consumption of 78¼ tons of coal, and running a total of 720 hours. The lift, friction included, was 378 feet. The duty performed in 1879 varied from 34,800,000 to 40,000,000 foot-pounds.

The Worthington engine has two double-acting plungers each 22 inches diameter, with high-pressure cylinder 36 inches in diameter, low-pressure cylinder 58 inches diameter, by 4 feet stroke. The capacity at 10 revolutions per minute is 295 gallons per revolution. During 1879 it pumped 979,914,480 gallons with a consumption of 3,287¼ tons of coal against a head of 345 feet, including friction, running in all 4,863 hours, developing a duty varying from 31,000,000 to 46,000,000 foot-pounds. To operate the Roxborough pumping-engines there are eight cylinder boilers, each 36 inches in diameter by 36 feet long, and two patent boilers of 100 horse-power each, with an evaporative power of 8 pounds of water to 1 pound of coal. The discharge-pipes from both engines combine into one of 20 inches diameter and 3,824 feet long, through which the water is forced into the Roxborough reservoir.

This has a capacity of 11,771,700 gallons, is 18 feet 6 inches deep, situated northeast of the pumping-works, and having a high-water area of 2 acres and 47 square rods, at an elevation of 365 feet above city datum. It is 410 feet long by 240 feet wide. The embankments are of earth faced with puddle 1 foot thick at top and 2 feet at bottom. Slope 1½ to 1. It is lined with brick laid on edge in cement.



PIPE-BRIDGE, ROXBOROUGH WORKS.



PLAN OF CHESTNUT HILL WATER-WORKS.

Mount Airy reservoir, supplied by gravity from Roxborough, is 15 feet deep, high-water surface 49,553.5 square feet, 363 feet above city datum, with a capacity of 4,390,000 gallons. The connecting main is 20 inches in diameter and 3.8 miles long, crossing the Wissahickon river by an inverted siphon, the difference in elevation between the two reservoirs being 2¾ feet, and the pipes at the bottom of the valley being under a head of 295 feet.

THE CHESTNUT HILL WORKS.

For the supply of Chestnut hill the city government in 1873 purchased for $65,000 the Chestnut Hill water-works. The water is taken from a well and a spring by two horizontal high-pressure engines, working one double-acting pump 7 inches in diameter by 4 feet stroke, and raising the water 125 feet into a tank with a capacity ot 40,000 gallons, through an 8-inch main 480 feet long. In 1876 an Olds pump was added. During 1879 the number of gallons pumped was 87,532,350, consuming 465 tons of coal in a total of 4,106 hours. At these works there are used two cylinder boilers, each 30 inches in diameter by 30 feet long, each having one drum 30 inches by 7½ feet.

On Roxborough ridge a pumping-station has been erected, the plan and elevation of which is shown in the figure, containing one Worthington engine with a pumping capacity of 400,000 gallons per day, and pumping into two tanks, each 30 feet in diameter by 6 feet deep, with a total capacity of 100,000 gallons, the water-surface of which is 440 feet above city datum. They are erected on trestle-work. These works are known as the Roxborough auxiliary, and in 1879, pumping one day in six, elevated 3,389,250 gallons 80 feet high, including friction, with a consumption of 61 tons of coals during 1,735 hours.

A stand-pipe formerly used in the West Philadelphia system, and shown on page 142, is to be removed to the Schuylkill works. It is 5 feet in diameter and 130 feet high, to be increased to 153 feet. The stone base is 37 feet high and 15 feet in diameter. One 38½-inch outlet and one 20-inch inlet.

The distribution is carried out through 730 miles and 1,171 feet of cast-iron main of the dimensions 48, 36, 30, 20, 18, 16, 12, 10, 8, and 6 inches, respectively, in diameter, in which there are 5,819 fire-hydrants known as the Philadelphia pattern.

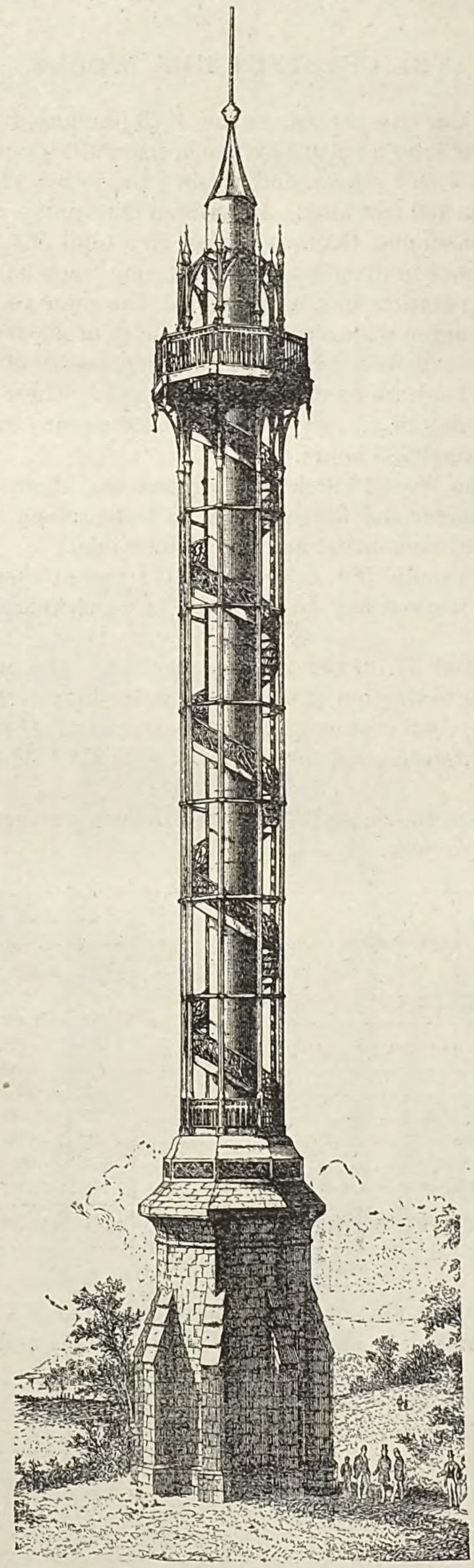
In 1880 the consumption averaged 57,707,082 gallons per day. The original cost of the old Schuylkill and Center Square works to the time of introduction of steam at Fairmount was $657,398. The cost of the Fairmount works to 1855 was $3,356,627, and the total cost of all works to January 1, 1880, is $15,828,331. The annual cost of maintenance for 1879, exclusive of extension and interest, was $295,278. The number of water-takers in 1879 was 150,000.

The annexed table gives analyses of the Schuylkill and the Delaware rivers at intervals since 1842. The figures represent number of grains in 1,000 gallons:

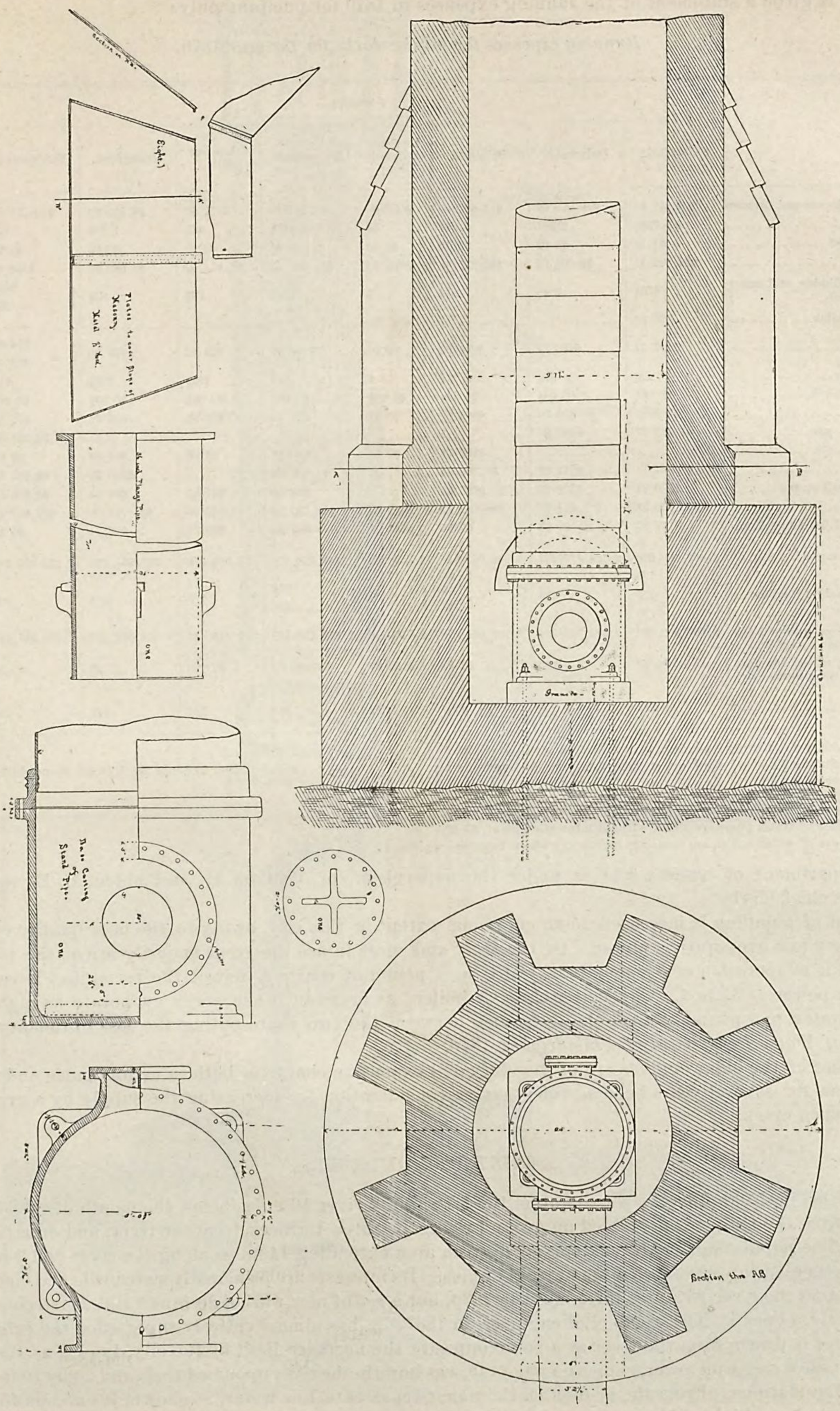
Constituents.	DATE OF ANALYSIS.			
	1842.	1854.	1862.	1875.
Lime	1,226	1,404	1,457	1,821
Magnesia	240	696	835	802
Soda	455	348	131	568
Sulphuric acid	302	1,417	1,508	2,445
Alumina and oxide of iron	77	68	75	Trace.
Chlorine	86	168	139	155
Silica and insoluble matter	385	(a)	339	348
Organic matter, carbonic acid, water of hydration, etc	1,650	2,008	2,556	1,999
Total solid matter per 1,000 gallons determined direct	4,421	6,109	7,040	8,138

a Undetermined.

There is a striking increase in the solid matter in the water from (4,421 grains) 10 ounces in 1842 to (8,138 grains) 18 ounces in 1875, gradually rising, as shown in the totals of 1854 and 1862.



WEST PHILADELPHIA STAND-PIPE.



DETAILS OF STAND-PIPE FOR SPRING GARDEN WORKS.

Below is given a statement of the running expenses in 1879 for pumping only:

Running expenses for all the works for the year 1879.

	WORKS.								Total.
	Schuylkill.	Delaware.	Belmont.	Roxborough auxiliary.	Roxborough.	Chestnut Hill.	Frankford.	Fairmount.	
Salaries of engineers and firemen	*a* $11,818 00	$10,575 00	$12,600 00	$300 00	$6,345 00	$777 60	$6,525 00	$10,575 00	$59,515 60
Coal (tons)	*b* 4,735½	2,981	8,619	61	3,865½	465	1,278	174	22,179
Price per ton	$3 13	$3 02	$2 70	$3 10	$3 60	$3 60	$3 20	$3 20	.....
Amount	$14,822 11	$9,002 62	$23,271 30	$189 10	$11,983 05	$1,674 00	$4,089 60	$556 80	$65,588 58
Lubricating, cylinder, and castor oil (gallons).	690¼	354¼	873	3	334¾	93¾	93½	260¾ 66¾	2,770
Price per gallon	*c* $0 30	.....	.....	*d* $1 10	.....	.....	.....	.....	.....
Amount	$207 07	$106 27	$261 90	$0 90	$100 42	$28 12	$28 05	$78 22 $72 43	$883 38
Tallow (pounds)	7,430	562	5,297	6	533	616½	386½	117	14,948
Price per pound	$0 09½	$0 09½	$0 09½	$0 09½	$0 09½	$0 09½	$0 09½	$0 09½	.....
Amount	$705 85	$53 39	$503 21	$0 57	$50 63	$58 56	$36 72	$11 12	$1,420 05
Lighting works, gas	$1,725 27	$990 96	.....	.....	.....	.....	.....	$2,254 51	$4,970 74
Lighting works, oil	.....	.....	$182 78	$0 76	$48 26	$5 98	$45 00	$6 03	$288 81
All repairs	$2,881 71	$811 18	$1,306 64	.....	$1,203 54	.....	$930 33	*e* $8,233 46	$15,366 86
Packing and small stores	$779 87	$139 95	$780 00	.....	$62 10	$47 83	$90 00	$1,099 83	$2,999 58
Total expenses	$32,939 88	$21,679 37	$38,905 83	$491 33	$19,793 00	$2,592 09	$11,744 70	$22,887 40	$151,033 60
Cost of raising 1,000,000 gallons into reservoir.	$7 37	$9 88	$9 84	$144 57	$17 34	$29 62	$15 34	$3 14	.....
Total gallons pumped	4,468,480,020	2,194,470,977	3,954,962,917	3,389,250	1,141,356,720	87,532,350	765,551,793	7,278,357,488	19,894,101,515
Lift, in feet, including friction	120 150 170	133	216 207	80	358 345	125	203	100	.....
Number of gallons pumped 100 feet high, friction included.	5,662,966,862	2,918,646,399	8,302,994,009	2,711,400	3,958,668,175	109,415,437	1,554,070,139	7,278,357,488	29,787,829,909
Cost of raising water 100 feet high per 1,000,000 gallons, friction included.	$5 82	$7 42	$4 69	$181 97	$5 00	$23 70	$7 55	$3 14	.....
Days run	293	353	365	364	365	365	247	364	.....

a $2,098, extra firemen, paid from item "Buildings and grounds".
b Including 523½ tons, banking, starting fires, and heating building.
c Lubricating oil.
d Castor oil.
e Rebuilding turbines No. 4, $4,622 05, not included.

Total expense of water pumpage alone, without interest on plant, $3 14.
Total expense of steam pumpage alone, without interest on plant, $5 69.
Total expense of water and steam pumpage together, without interest on plant, $5 07.

The department of water-works is under the supervision of William H. McFadden, C. E., with Mr. J. T. Hickman as chief clerk.

The cost of pumping is increased to an enormous extent in this city, owing to the poor quality of the boilers and their very low evaporative power. Of the sixty and more in use the great majority are of the plain cylinder type, with an evaporation of 5½ pounds of water to a pound of coal. A few of the remaining have as high an evaporative power as 8½ to 1. The better class of boilers as found in other works evaporate as high as 10 to 12 pounds of water to a pound of coal, the difference between the two representing the loss to the city every year. See *Report of Water Department of Philadelphia*, 1876.

A number of the older engines are of low duty and expensive character both in maintenance and in first cost.

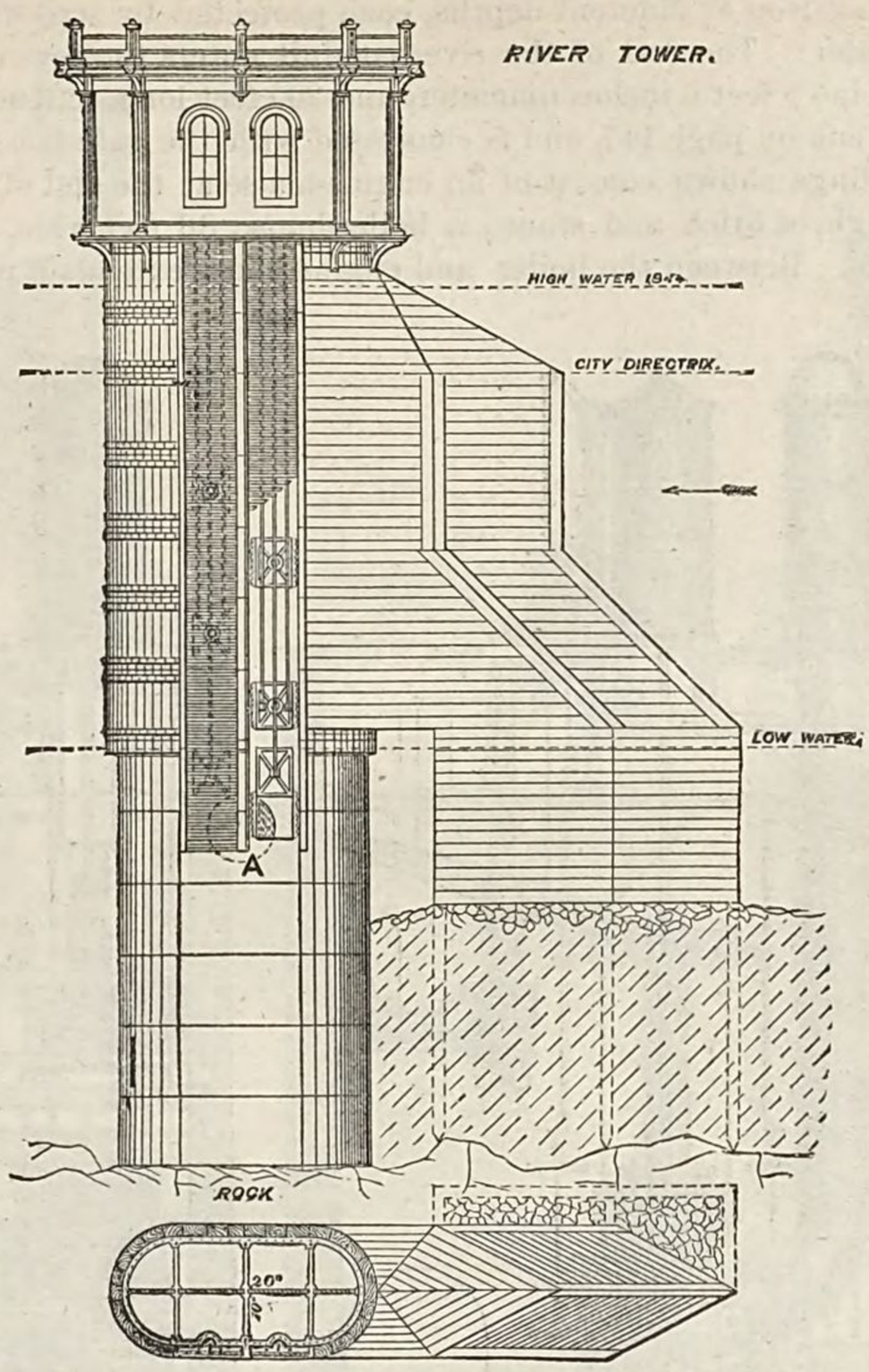
There has for several years been a project under consideration for increasing the supply by a gravity system from Perkiomen creek.

SAINT LOUIS, MISSOURI.

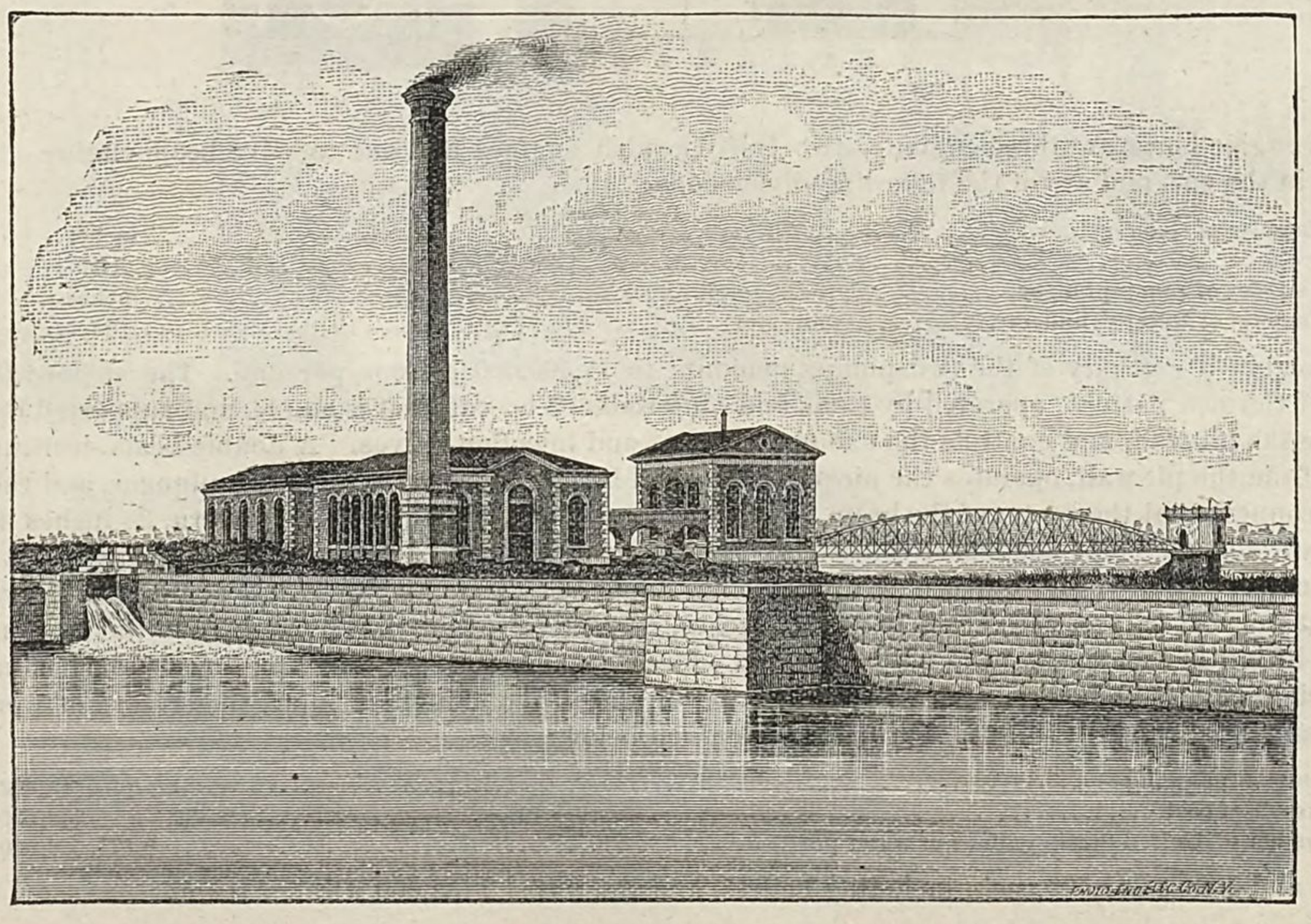
Saint Louis is situated on the west bank of the Mississippi river 16 miles below the mouth of the Missouri, and 1,294 miles from the Gulf. It is located on ground rising in three terraces from the river, and on a foundation of limestone. The population, 350,518, is spread over an area extending 14 miles along the river and 9 miles inland. The streets generally intersect each other at right angles. Its interests are principally mercantile and manufacturing.

Water from the river was first introduced in 1830, but a set of new works, designed and constructed under the direction of Mr. James P. Kirkwood, civil engineer, in 1867–'72, has almost entirely superseded the original plant.

The water is drawn from the river at a point opposite the northern limit of the city, known as Bissell's point. For this purpose a cast-iron tower, shown on page 145, was built in the river upon bed-rock, and 20 by 10 feet by 38 feet high above foundations. From the 36-foot mark, which represents low water, as shown, it extends 45 feet higher to a point just above highest known level, and is surmounted by a gate-house. On one side of this inlet-tower, as



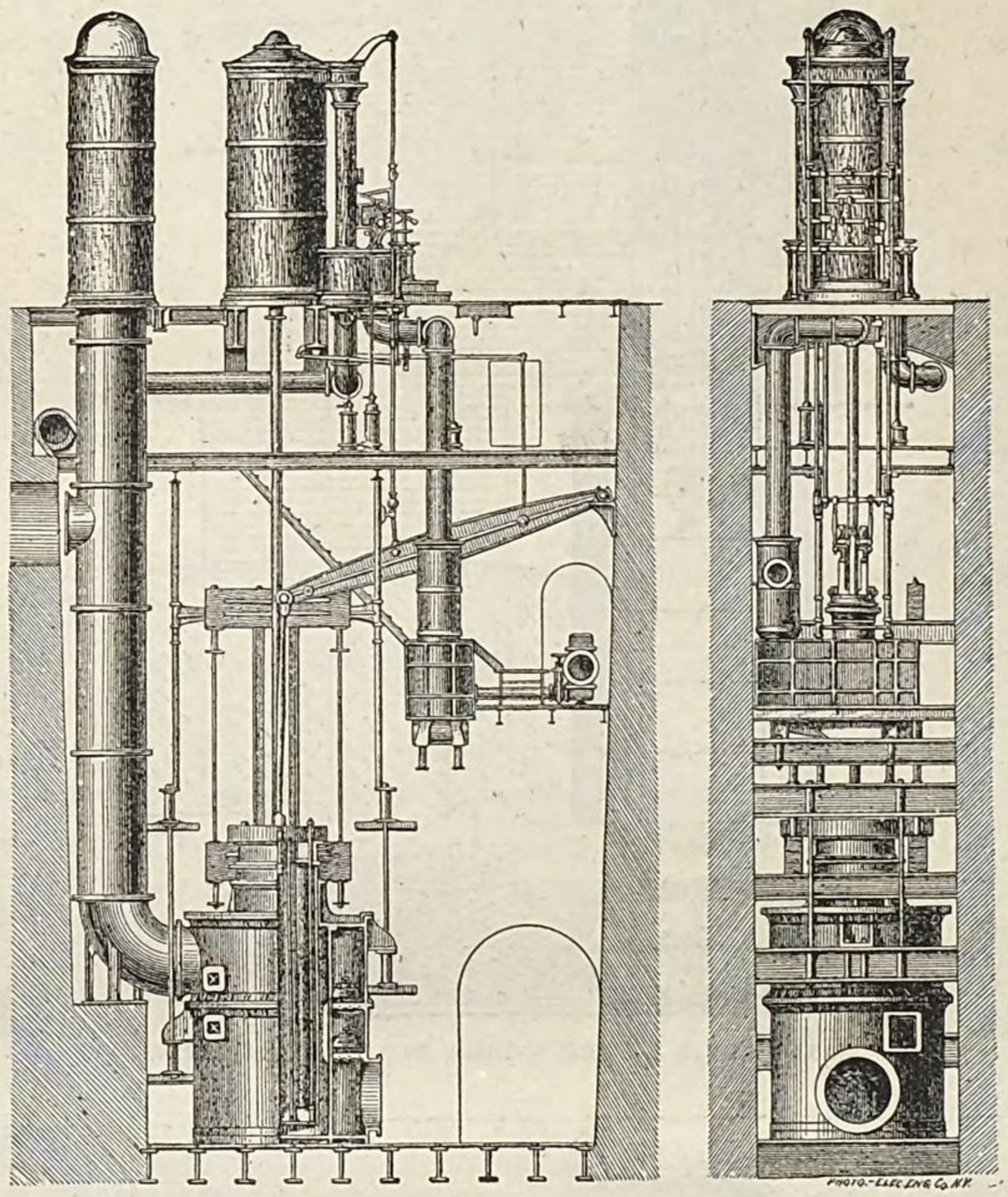
SAINT LOUIS WATER-WORKS, PLAN AND SECTION.



PUMPING STATION OF SAINT LOUIS WATER-WORKS.

shown, there are six gates of cast iron at different depths, each protected by screens. The one usually used is at 5 feet below the level of the water. The end of the river conduit enters the tower 10 feet below low-water mark at A, and consists of an iron pipe 5 feet 6 inches diameter, and 200 feet long, extending to the pumping station.

The latter is shown in the cut on page 145, and is connected with the gate-house of the inlet-pier by the iron bridge there shown. The buildings shown consist of an engine-house at the end of the bridge, 50 feet wide by 42 feet deep by 35 feet 8 inches high, of brick and stone; a boiler-house 86 feet wide, 57 feet deep, and 26 feet high, and a coal-shed of the same size. Between the boiler- and engine-house extends a pipe bridge.



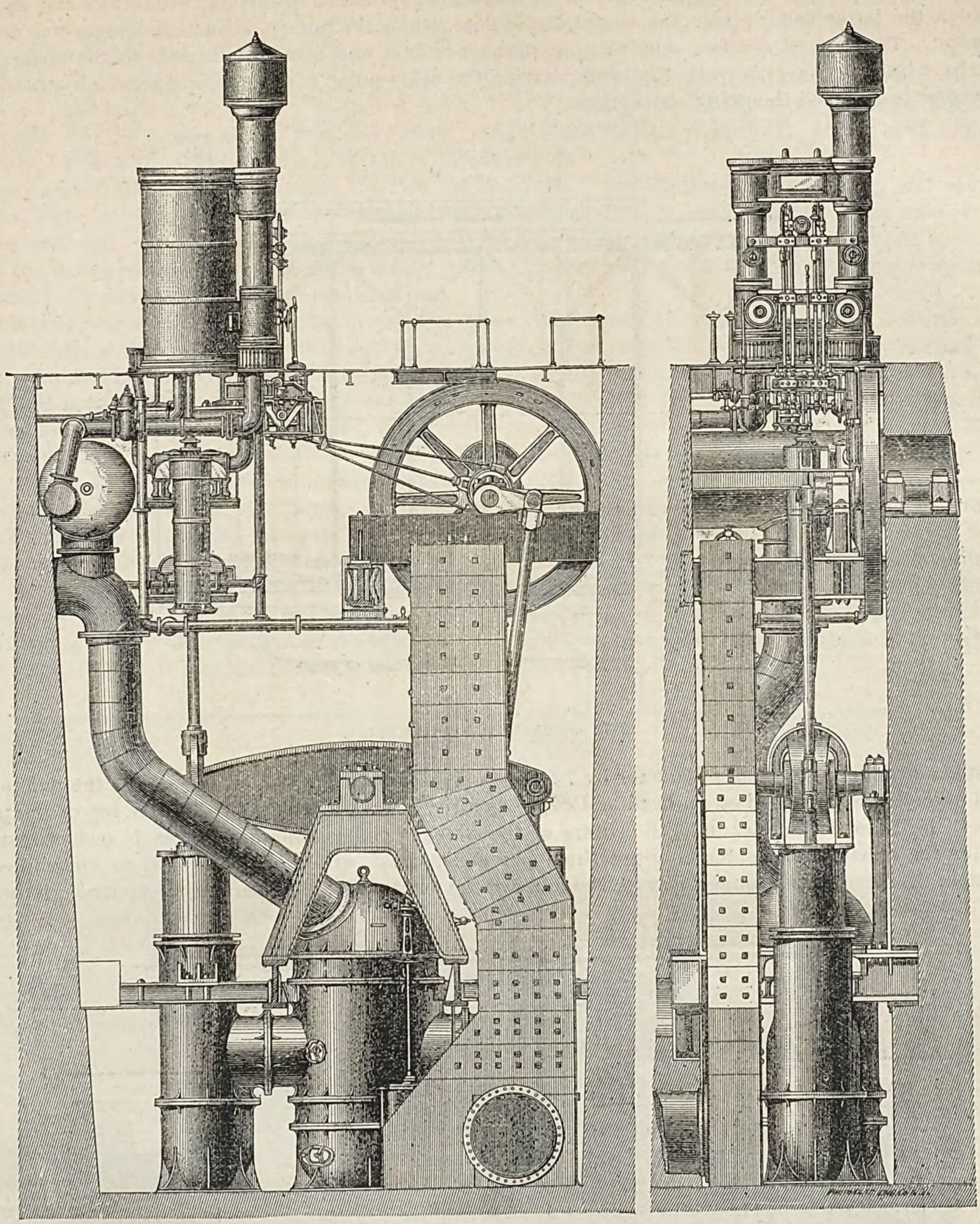
In the engine-house are three engines—two Bull Cornish engines and one rotative beam-engine. The former are shown in the cut, and are of the following dimensions:

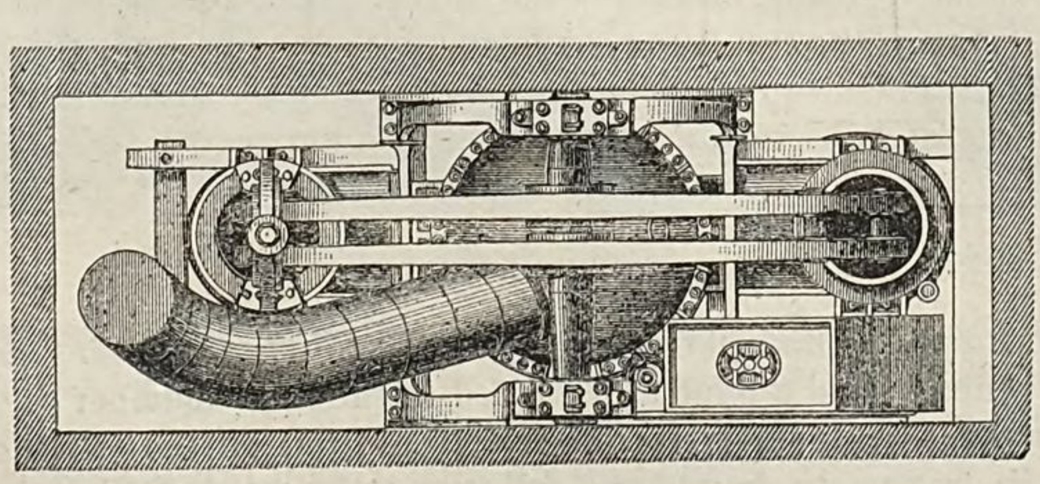
Diameter of steam-cylinder	inches	56
Stroke	feet	12
Diameter of pump-plunger	inches	56
Diameter of water-cylinders	do	72

The combined capacity of the two pumps amounts to 17,500,000 gallons per day. The steam-valves are of double-beat Cornish pattern, operated by cams and plug-rods. The cataract is single, and supported on a bracket attached to the pit-wall, and controls the exhaust-, steam-, and injection-valves. A double beam, working on a pin supported from the pit-wall, operates the air-pump, one end being connected to the pump-plunger, and the air-pump rod being connected at the center of the beam. The air-pump is of the single-acting pattern, 28 inches diameter by 72 inches stroke. The pipe-condenser consists of two vertical pipes joined by a flange, one being 5 feet long by 21 inches diameter, and the other 5 feet long by 30 inches diameter. The pump-cylinders contain 24 Harvey & West double-beat Cornish valves, with seats 16 and 14 inches, respectively, in diameter, with 12 in the suction and 12 in discharge, lifting $1\frac{1}{4}$ inch each. The induction- and eduction-mains and the stand-pipe are 48 inches in diameter, and the rising-main is 36 inches, with valves in the latter and in the induction-main. The record of work done by these two and No. 3—April, 1879, to April, 1880—is given below:

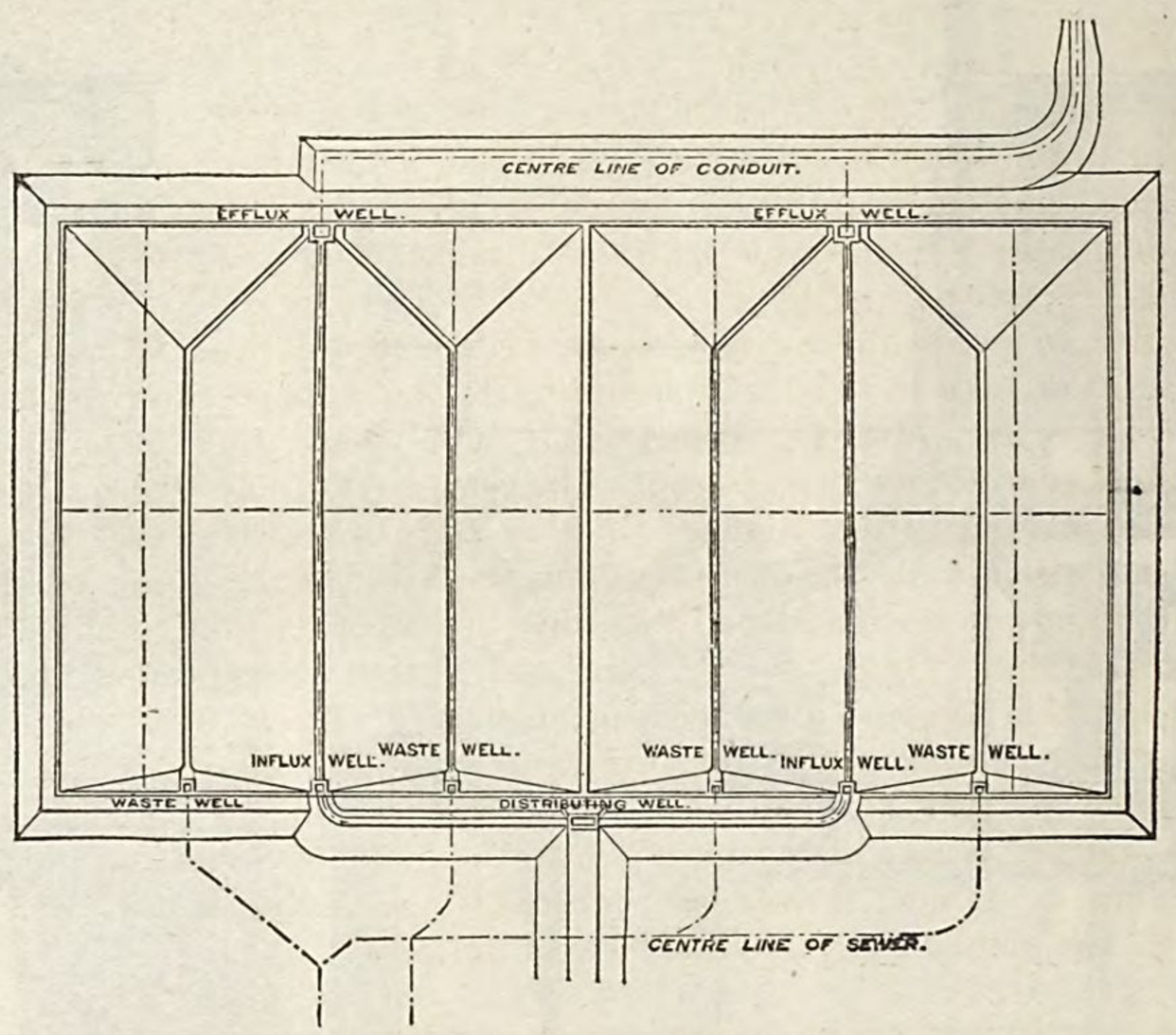
Hours of pumping	$13,462\frac{3}{8}$
Bushels of coal	268,636
Number of United States gallons of water pumped	8,871,583,000

Nos. 1 and 2 cost $47,500 each, including boilers, and No. 3 cost $132,000 without them.



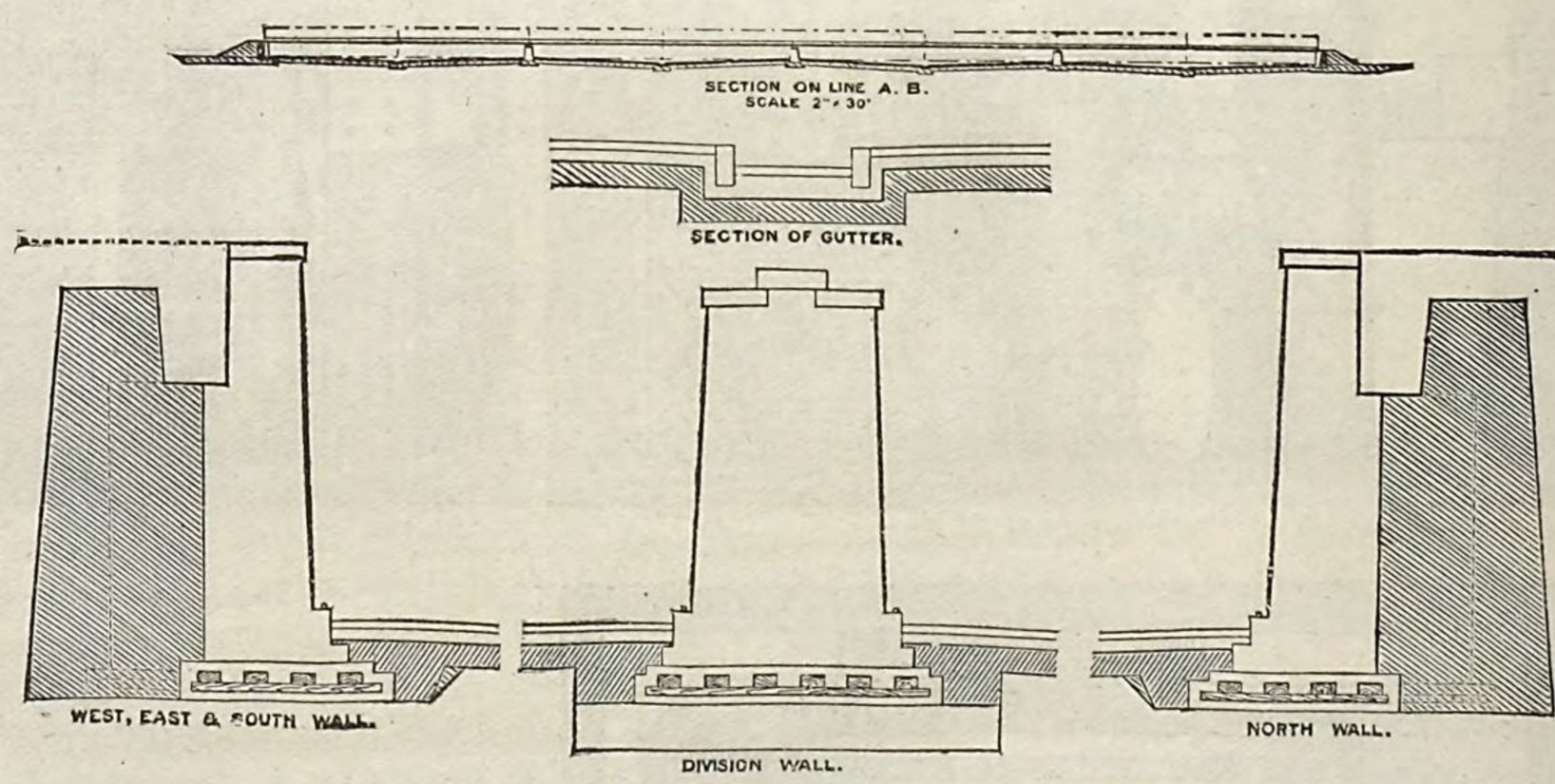


Engine No. 3 is a double-acting condensing beam-engine, as shown in the cut, with crank and fly-wheel and one cylinder, the latter being above the engine-house floor, while the pumps, beam, condenser, etc., are below in the pump-pit. The pumps are two single-acting plunger-pumps, one attached directly to the steam-piston rod and then by a linked connection with the beam, driving the other pump at its opposite extremity, between which and the center is attached the crank-connection.



PLAN OF SETTLING RESERVOIRS.

The steam-cylinder is 60 inches diameter by 7 feet stroke, and bolted to two girders across the pump-pit. The piston-rod extends through the bottom head and connects directly with a yoke bolted to the top of the plunger of the pump. The beam is double, and the centers of the plunger connections are 21 feet 7½ inches apart. From the cylinder the exhaust-pipe extends above the upper steam-chest, with a bell-cap for river-water injection and condensation. A 5-inch pipe, connected with the dome of the pump-valve chamber, passes up through the exhaust-



CROSS SECTIONS THROUGH WALLS OF SETTLING RESERVOIRS.

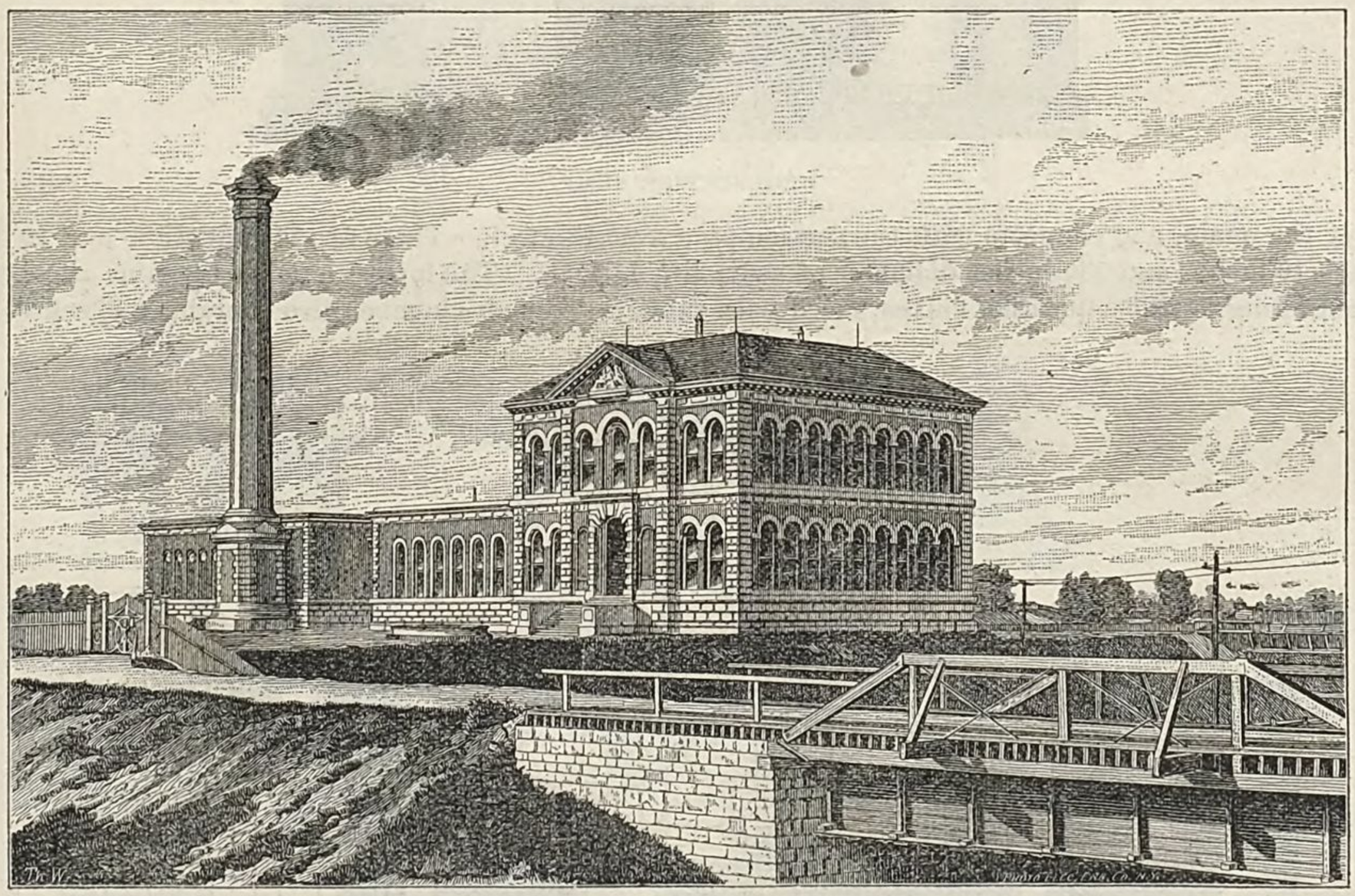
side pipe and discharges water into a shower-tank in the bell-cap condenser. The shower falling condenses the steam, which is caught with it in the funnel beneath, and a 6-inch pipe is led to the inlet-chamber of the air-pump. The air-pump is single-acting, 26 inches diameter, with its piston on the piston-rod of the steam-cylinder, and forming a coupling with it. It is open at the bottom to enable the follower to be set up without removing the head. The stroke is the same as that of the pump, and the valves are 1-inch rubber, 24 by 16 inches, on inclined seats. The hot-well is a small tank resting on girders supporting the steam-cylinder.

The valve-chamber to the two pumps is placed between them, circular in plan, 9 feet in diameter. The water from the river is received in an open tank of boiler-iron on the south side of the outer pump, resting on the bottom of the pump-pit, and extending to within 1 foot of the engine-room floor. The induction-pipe from the well to the valve-chamber is a rectangular pipe, with a cast-iron slide-gate 5 feet 8 inches by 3 feet. The force-main is 40 inches diameter, and curved as shown. The air-chamber, 6 feet diameter by 13 feet long, is placed horizontally and transversely over the force-main. The steam-valves are of the double-beat pattern, 11½ and 12 inches diameter; exhaust-valves, 15¼ and 16 inches diameter, Wright's patent cut-off.

To supply steam, there are eight 2-flue Cornish boilers, each 7 feet diameter, 30 feet long, and containing 33-inch tubes. The settling-drum, 15 inches diameter and 15 inches deep, is placed on the under side of each, 5 feet from the back end. The 33-inch flues are 19 feet and 10 inches long. The two furnaces in each boiler at the front end of the flues are each 2 feet 9 inches wide by 5 feet 6 inches long and 2 feet high. Their evaporation is said to amount to 7½ pounds of water per pound of coal.

From this pumping-station, known as the low service, the water is forced through three 36-inch cast-iron mains a distance of 365 feet, with a lift of from 15 to 50 feet, according to the stage of the river, into four settling basins, shown in the cut, and used alternately—two as settling, one as supply-basin, and the other one being filled. They are each 600 feet long by 270 feet wide and 19 feet deep. The construction may be seen from the cross-sections.

The sides are faced with masonry 4 feet 7 inches thick at the bottom by 3 feet thick at the top. They are backed with puddling. The division-walls between the basins are 8 feet thick at the top by 13 feet thick at the foundation. The method of filling can be understood from the position of the influx-wells. The bottoms are formed of brick laid on edge with cement. Owing to the immense amount of suspended impurity always found in Mississippi River water below the Missouri, a sediment of about 16 inches in depth has to be removed from the bottom of the basins about once in four months by a system of hydraulic mining. The water is drawn from the basins by a brick conduit 1,100 feet long, 6 by 5¾ feet in diameter, extending to the clear-water well. The latter is 150 feet long by 100 feet wide by 17 feet deep, and a brick conduit 13 by 8 feet and 120 feet long conducts the water to a chamber 50 by 9 feet containing the screens. Three 60-inch iron pipes pass from here to the well of the high-service pumps 12 by 87 feet and 39 feet below the level of the floor.

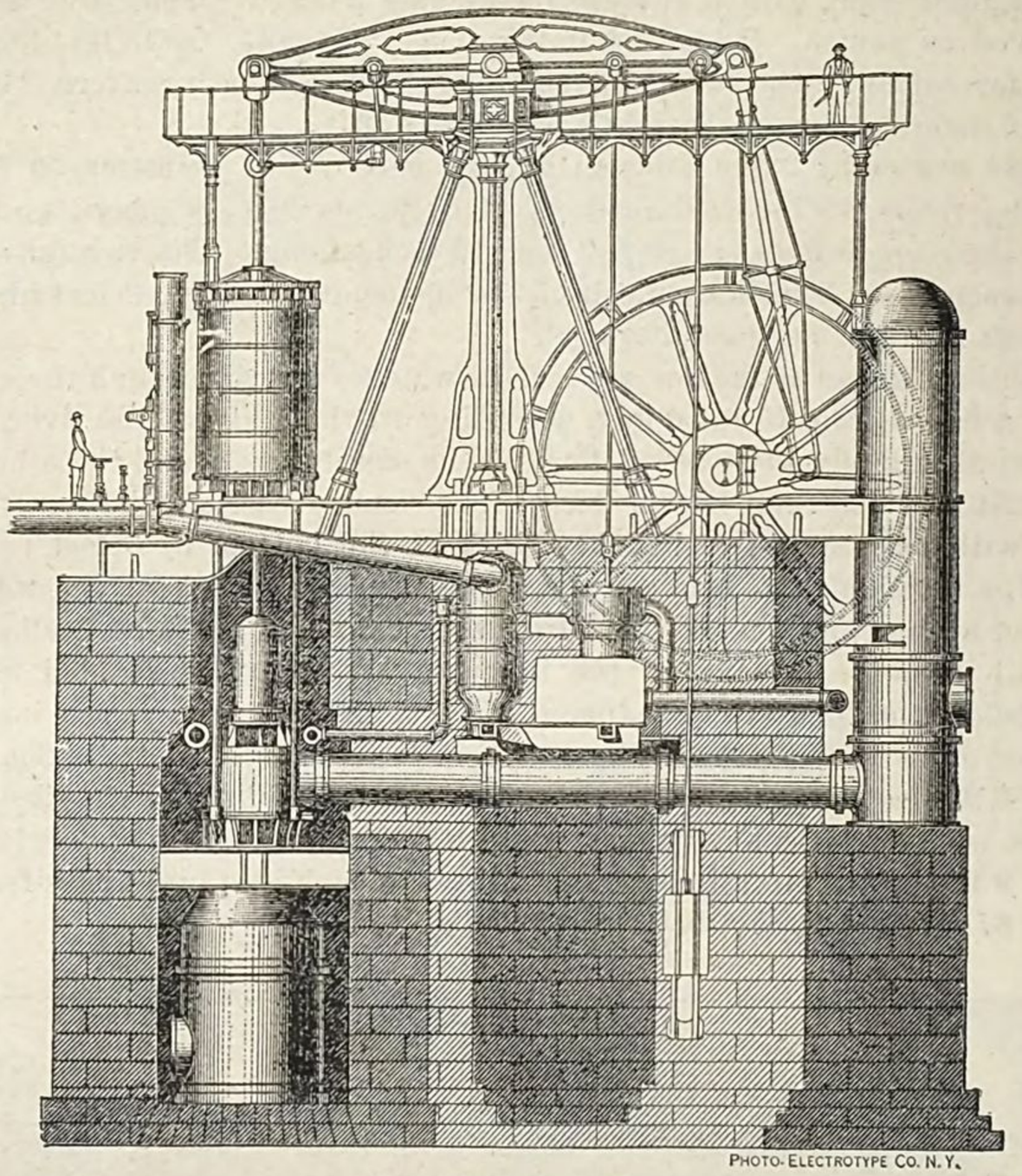


SAINT LOUIS WATER-WORKS, HIGH-SERVICE PUMPING-STATION.

The high-service pumping-station comprises an engine-house, boiler-house, coal-shed, machine-shop, and chimney, which may be seen in the cut. The engine-house is 86 feet wide, 92 feet deep, and 63 feet high. The boiler-house is 73 feet wide, 88 feet deep, and 37 feet high. The coal-house is 103 feet wide, 63 feet deep, and 37 feet high. Chimney, 134 feet high. They are all of brick trimmed with stone.

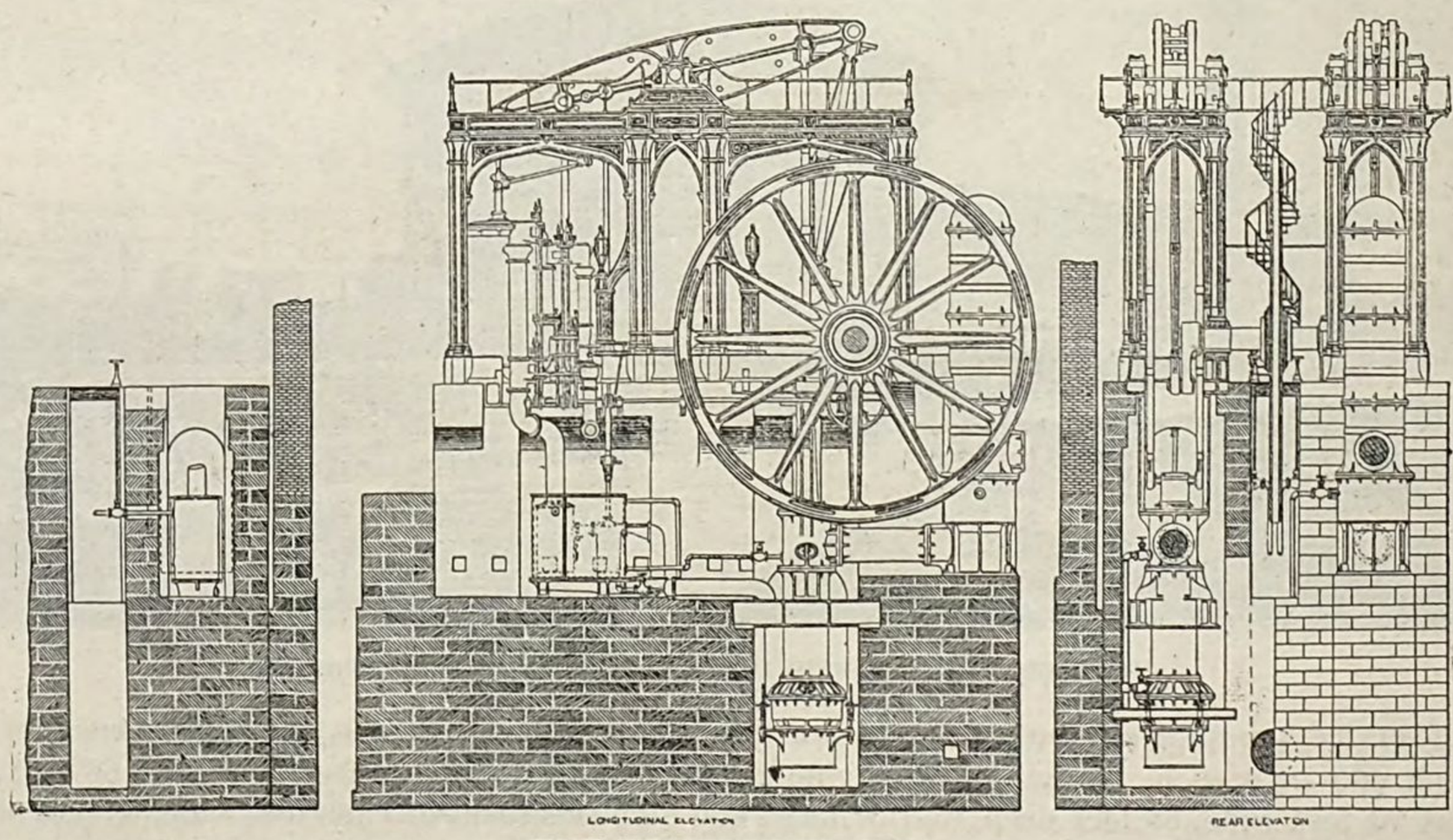
Two engines, known as the high-service pumps, receive the water from the well above mentioned, and force it into a distributing reservoir on Compton hill. These engines are double-acting condensing beam-engines, with crank and fly-wheel, and are shown in the cuts on page 150. The cylinders are 85 inches in diameter and 10 feet stroke,

operating a bucket-and-plunger pump, 51 inches diameter of plunger and 10 feet stroke. The capacity of each is 16,500,000 gallons. The pump is placed beneath the steam-cylinder in a dry well of masonry, the pump-rod being coupled to the steam-piston rod extended down through the bottom of the cylinder. A nozzle is cast upon the lower



HIGH SERVICE PUMP.

chamber of the pump, and connects with the suction-pipe from the well. There are 11 induction- and 10 eduction-valves, each 16 inches and $13\frac{3}{4}$ inches diameter of seat; lift, $1\frac{1}{8}$ inch. The lower chamber contains a foot-valve for suction, consisting of 22 composition valves, faced with rubber. The air-chamber also contains a check-valve.



HIGH SERVICE ENGINE NO. 3.

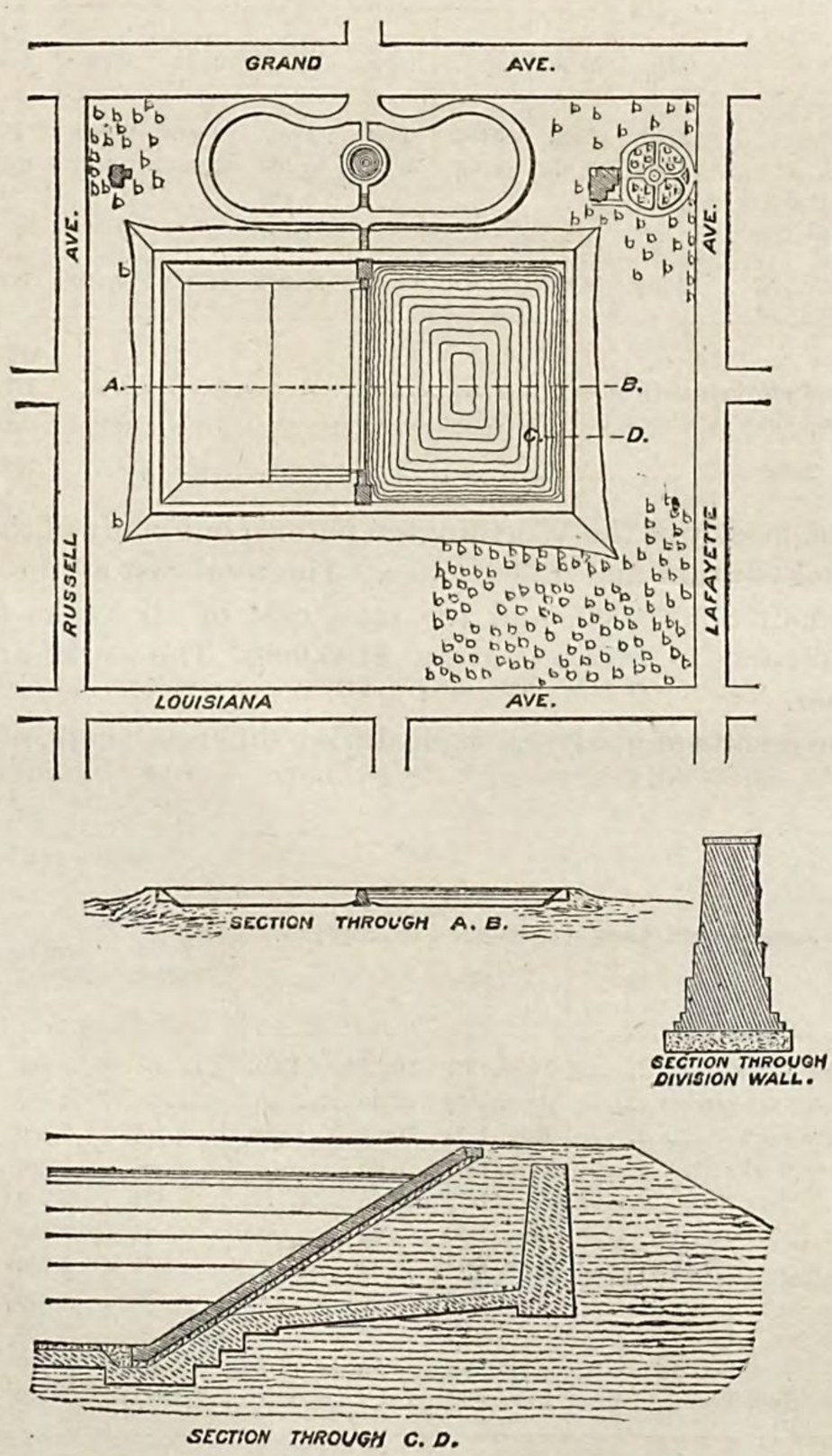
These engines were guaranteed to pump 16,500,000 gallons each to a height of 181 feet, through two mains, one 36 inches diameter and 18,500 feet long, and the other 30 inches diameter and 8,700 feet long, with a duty of

60,000,000 foot-pounds. The annexed table will show the work performed by all three of the high-service engines during 1879–'80. The pump-bucket contains a double-beat Harvey & West valve. Cost of engines, $121,000 each, including boilers.

The record of work done by high-service engines from April, 1879, to April, 1880, is as follows:

Hours of pumping	13,148⅔
Number of revolutions	8,782,700
Bushels of coal	688,638
Number of United States gallons of water pumped	8,692,473,000
Hours of pumping, engine No. 1	3,913½
Hours of pumping, engine No. 2	4,509⅙
Hours of pumping, engine No. 3	4,726
Total	13,148⅔

There are two batteries of eight return drop-flue boilers to operate the three engines, each 6 feet diameter and 24 feet long, containing 6 flues. The products of combustion pass from the furnaces (with grates 5 feet 2 inches by 5 feet 6 inches) through the four upper flues, each 13 inches diameter by 16 feet long, and return through the two lower ones, 19 inches diameter and 13 feet 10 inches long.



RESERVOIR AT COMPTON HILL.

Engine No. 3, built by the Hartford Machine Company, in 1875, and shown in the cut, is double, consisting of two separate engines coupled to the same shaft and fly-wheel. Each is a double-cylinder or compound condensing engine, with low-pressure cylinder 80 inches diameter, and high-pressure 50 inches diameter, with a stroke of 11 feet for the low-pressure and 87 inches for the high-pressure, and daily capacity of 24,000,000 gallons. The pumps are bucket-and-plunger and the air-pumps and condenser are located in the pit beneath the cylinder. The former is double-acting, 23 inches diameter by 54 inches stroke, and the latter is 40 inches diameter by 7 feet stroke. The pumps have 45¼-inch buckets, and plunger 32 inches in diameter and 100 inches stroke. The pump-valves are

similar to those in high service engines Nos. 1 and 2, and are 15 by 12 inches diameter of seat; lift, 1⅝ inch. From the high-service pump-well the water is forced into the storage-reservoir on Compton hill, a lift of 181 feet; midway of this distance the stand-pipe (a Corinthian column) is erected at a height of 100 feet above the pump-well. This stand-pipe is 160 feet high by 48 inches in diameter. It has one inlet and two outlets. One of the latter extends to the reservoir direct and the other to the city. Each is 36 inches in diameter. The plan and details of construction of the reservoir can be seen in the cut. It is 22 feet deep, 870 feet long by 540 feet wide at high-water mark, with a slope inside and out of 1½ to 1. The banks are 18 feet wide at the top, with a puddled wall 4 feet wide at the top, which is 2 feet above high-water level and 7 feet thick at the base and 18 feet high. The offset of puddle shown in the figure is 2 feet thick, and a like thickness extends under the whole bottom of the reservoir. The riprap facing is about 16 inches thick, resting on an 8 inch layer of gravel, and consists of rubble laid dry. The division-wall of masonry divides the reservoir into two compartments. The capacity is about 60,000,000 gallons. The bottom is protected by a layer of 6-inch concrete. High-water surface is about 176 feet above city datum. From here a cast-iron supply-main connects with the distribution system. The force-main enters the reservoir at the bottom, and is connected with the distribution system so that only the surplus above consumption passes into it, amounting to about 10,000,000 gallons daily. The daily consumption amounts to about 25,000,000 gallons, supplied through about 200 miles of cast-iron main, the sizes and lengths of which can be seen in the annexed table:

Date of laying mains.	36-inch.	30-inch.	20-inch.	15-inch.	12-inch.	10-inch.	8-inch.	6-inch.	4-inch.	3-inch.	Miles.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Total.*
Previous to October 6, 1877	33,213	16,670	76,024	41,969	35,591	45,130	.....	608,626	9,329	68,414	177.077
From October 6, 1877, to April 8, 1879	.....	.....	.....	.....	1,070	.....	.....	75,017	.....	.....	14.410
From April 8, 1879, to April 8, 1880	.....	.....	.....	.....	1,677	1,213	3,570	36,375	.....	.....	8.113
Total	33,213	16,670	76,024	41,969	38,338	46,343	3,570	720,018	9,329	68,414	199.600

	Miles.
Total laid previous to October 6, 1877	177.077
Total laid since October 6, 1877	22.523
Total	199.600

About 573 meters are in use, mostly of the Worthington patent, but many of the Crown and Union patents. On this system there are 1,696 fire-hydrants and 1,606 gates. The total cost of the old works up to the time of the completion of the new was about $3,000,000, and the total cost of all works is now between $12,000,000 and $13,000,000. The cost of maintenance in 1879 was about $195,000. The works are now controlled by Mr. Thomas J. Whitman, water commissioner.

The annexed table gives the results of analyses, made during different years, of samples taken at different points of the works:

Location from which samples were taken.	Date.	Analyst.	GRAINS PER GALLON.			Hardness, degrees.
			Solid matter.	Organic matter.	Solid matter separated by filter.	
River, opposite works	June, 1871	Dr. Theo. Fay	.....	0.504	232.00	7.050
Hydrant, Walnut and Sixth streets	Aug., 1872	....do	.....	0.420	None.	4.900
River, 2,500 feet above works	Aug., 1873	Dr. D. V. Dean	161	2.380	134.00	8.333
River, 2,500 feet above works	Dec., 1873	....do	94	3.360	79.00	6.095
Influx-chamber	Aug., 1873	....do	171	2.940	138.00	8.031
Influx-chamber	Dec., 1873	....do	91	3.500	72.00	5.342
Influx-chamber	May, 1874	....do	134	1.500	107.00	7.894
Clear well	Aug., 1873	....do	36	0.840	12.00	6.740
Clear well	Dec., 1873	....do	51	2.660	40.00	5.000
Clear well	May, 1874	... do	31	0.800	6.00	6.992
After remaining in settling basin 8 hours	Feb., 1874	Dr. Theo. Fay	.....	1.570	2.64	6.653

The influx-chamber receives the water from the river-engines and distributes it to the various settling basins. The water taken from this chamber would be the same as if taken from the river opposite the works at the same time. The clear well receives the settled water after it has passed through the basins. Samples taken from this well would indicate the quality of the water that was being pumped into the city at that time.

The quantity of sediment deposited from the water in the basins may be taken to average for nine months of the year from 7 to 9 parts (by measure) in 1,000, and for the remaining three months it will average about 3 parts in 1,000.

No regular system of duty-trials of engines in the Saint Louis system has ever been made, so that a comparison of their values can not be instituted.

NEW ORLEANS, LOUISIANA.

New Orleans, with a population of 216,090 inhabitants, is situated on the east bank of the Mississippi river, 120 miles from its mouth. Its interests are almost exclusively commercial. Its site is level, and lies from 4 to 12 feet below high-water level in the river, the water being excluded by dikes or levees. The city extends its limits eastward to lake Pontchartrain, and the soil upon which it is built is a black alluvium of sand and clay. The plan of the city is rather irregular. In 1837 a company introduced a supply of water from the river for fire-protection and all domestic uses save drinking, the water being too impure for the latter purpose. Drinking-water is largely derived from large elevated wooden cisterns at the rear of every house, into which the rain-water falling upon the roofs is collected. In many of the cisterns an arrangement of stop-cocks permits the exclusion of the first washings of the roof during a storm and the collection of the subsequent fall. As a matter of fact this apparatus is seldom attended to, and as a result the drinking-water is any thing but pure. Some people filter the river-water for drinking. Water is taken from the river by means of an iron pipe the outer end of which is sunk in a crib. From this point, which is within the city limits, the water enters the pump-well within the engine-house. The latter consists of two square brick buildings, the one containing the old engines and the other the new; while a small building behind them contains a compound Knowles pump. The old engine, built by the Allaire Works, of New York, after designs by Erastus W. Smith, in 1837, with a capacity of 7,000,000 gallons, is a condensing beam-engine, two of them being coupled to the same fly-wheel. They are of the following dimensions: Steam-cylinder, 30 inches diameter; pump-cylinder, 21 inches diameter; stroke, 6 feet. Jet-condenser, 30 inches diameter; depth, 30 inches. Air-pump, 20 inches diameter; stroke, 40 inches.

The condenser is placed immediately beneath the steam-cylinder. The average speed of the engine is 16 revolutions per minute. There is one piston-plunger to each engine, and the pump-cylinders contain two double-beat suction- and two delivery-valves about 12 inches diameter by 3 inches lift, and mechanically operated by cams and plug-rods. The steam-valves are double-beat puppet, operated by plug-rods, bent lever, and eccentrics. There seems to have been no duty-trial.

The new engines, also designed by E. W. Smith, but built in 1868 by the New York Novelty Works, at a cost of $48,000, are very similar to the old ones. There are two coupled to the same fly-wheel and of 14,000,000 gallons capacity. They are condensing beam-engines with steam-cylinders 57 inches in diameter and 8 feet stroke; pump-cylinders, 28 inches in diameter, 8 feet stroke. The construction is essentially the same as in the old engines. The water-valves are also double-beat, 2 suction and 2 delivery, each 20 inches diameter by 7 inches lift. All the pumping-engines have double-acting pumps. The jet-condenser, located as before, is 5 feet 8 inches diameter by 3 feet 6 inches high, with an air-pump 32 inches diameter by 4 feet stroke. The speed of the engine averages 10 revolutions per minute.

There are 8 boilers in use for the two sets of engines—4 being used with the new, 2 with the old, and 2 idle. They were made by John Armstrong, of New Orleans, are 42 inches diameter by 30 feet length of shell, with two 15-inch flues in each, and burn Pittsburgh coal, with a pressure of 20 pounds. Their evaporation is unknown.

The Knowles pump, of 5,000,000 gallons capacity, was built in 1880. It is compound condensing, with high-pressure cylinder 38 inches diameter, 3 feet stroke; and two low-pressure, 20 inches diameter, 3 feet stroke, one on each side of the high-pressure cylinder. These operate directly a double-acting piston plunger 26 inches in diameter. The duty of the engine is given at 50,000,000 foot-pounds, and the average speed 22 revolutions per minute. It is used as an auxiliary in case of failure or repair in the large engines. In the pump-valve chambers there are a large number of 3-inch suction- and discharge-valves of disk-shaped rubber, confined by a spiral spring. The air-pump is a small Knowles pump, seen in the rear of the floor of the engine-room. It is 16 inches diameter by 21 inches stroke. The jet-condenser is 24 inches diameter by 26 inches high, and is located just above the air-pump. There is a battery of two multitubular boilers, made by Ed. P. Hampson, of New York; they are 54 inches diameter by 16 feet long, with 46 tubes 3½ inches diameter in each. The pressure averages 50 pounds. The total cost of this pump, including boilers erected, was $12,000.

From the engine-house the water is forced partly into the stand-pipe for high buildings, and partly into the reservoir. The former is 200 feet from the pumps, and in the yard a 30-inch main connects them. It is of wrought iron, 150 feet high, 6 feet diameter at bottom by 4 feet at top, with a small and low base of brick-work. There are two 36-inch inlets and two outlets, one of 30 and the other of 36 inches. It is an economical but handsome structure.

The reservoir was originally a large brick basin or tank, 250 feet square, with perpendicular brick-masonry walls, backed on the outside by earth embankments, and divided by 5-foot brick walls into four compartments, each 120 feet square. A few years ago two of the compartments gave way, and only two are at present in use, of about 1,000,000 gallons capacity each. The depth is 10 feet. The sides and bottom are of brick in cement, 2½ feet thick. The reservoir is situated within the city limits, and about 1,100 feet from the engine-house. It has a head of only 28 feet, and is used to supply the low-lying districts. Without the stand-pipe the maximum pressure is 30 pounds at the pumps.

In December, 1880, there were 81 miles of mains, 3, 4, 6, 8, 10, 12, 16, and 18 inches in diameter, with main supply-pipes of 36, 30, and 20 inches. The distribution pipes are mainly cement-lined wrought iron, with about 8 or 9 miles of cast iron. Much of the former is being replaced by the latter.

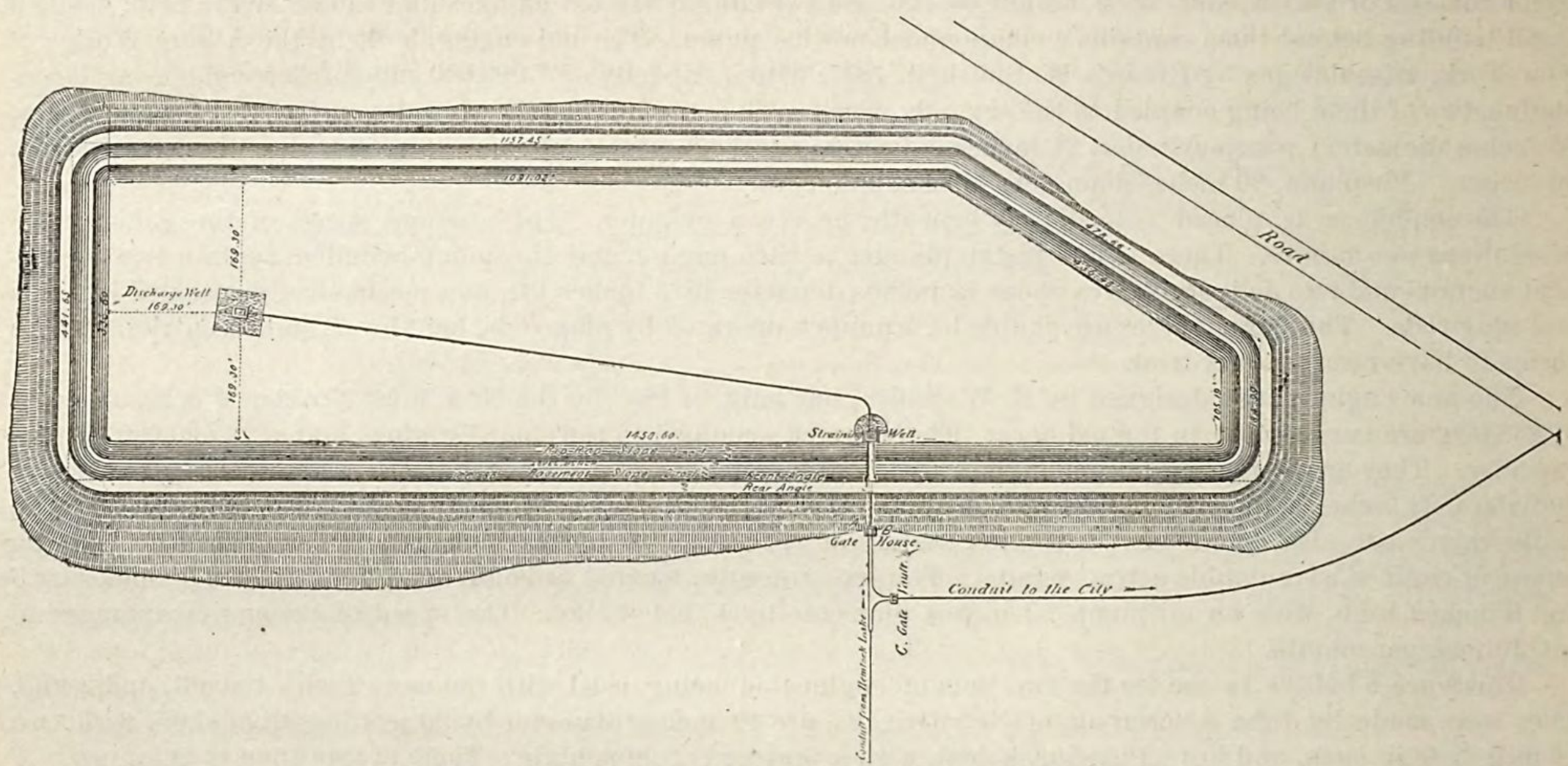
There are 1,200 hydrants in the city, of different patents. The most recent ones, however, are Matthews' patent.

The number of takers being 6,000, the consumption averages about 9,000,000 gallons per day.

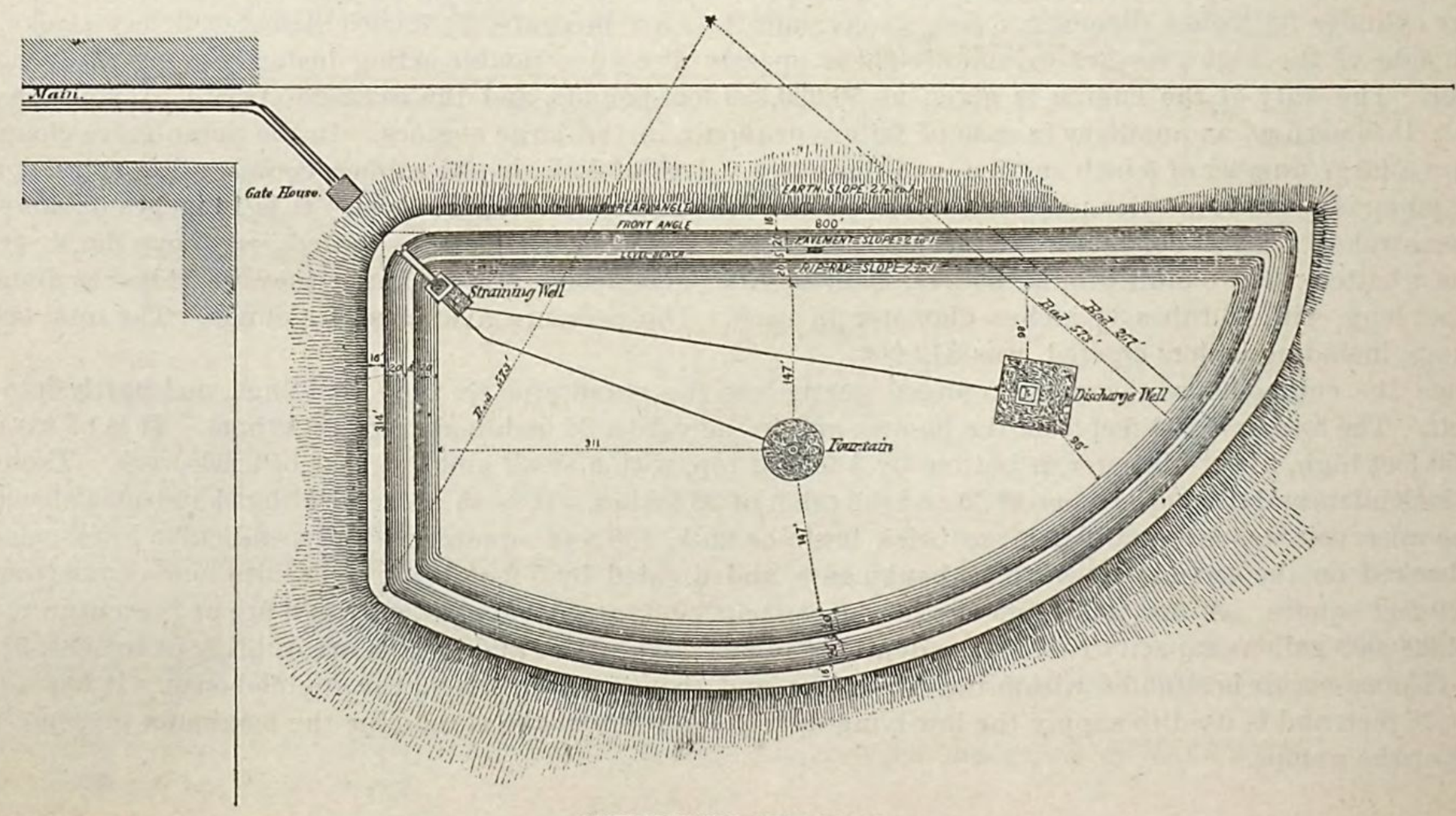
The original cost of the works was $2,000,000, increased to $2,300,000 to date. The annual cost of maintenance is about $45,000, and revenues for 1879 were $91,371. Improvements are at present under way, in charge of Mr. Moses Lane, civil engineer. The present chief officer of the company is Mr. Edward Toby, president and superintendent.

ROCHESTER, NEW YORK.

Rochester has a population of 89,366 inhabitants, and is situated upon both sides of the Genesee river, 7 miles from its mouth. Its site is level, resting upon strata of shale and limestone, and its streets are regular. Its interests are commercial and manufacturing.



ROCHESTER WATER-WORKS—PLAN OF THE STORAGE RESERVOIR AT RUSH.



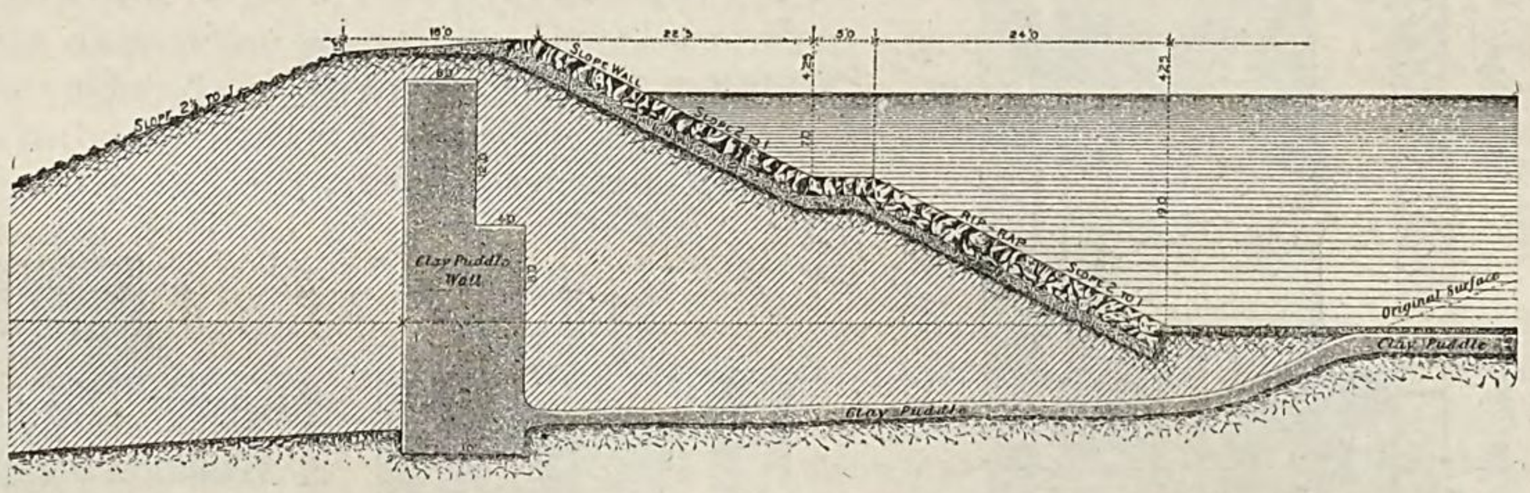
MOUNT HOPE RESERVOIR

In 1874, under the direction of the present engineer, water-works were built, deriving the supply, first, by gravity, from Hemlock lake, 30 miles south of the city, and, second, by pumping from the Genesee river.

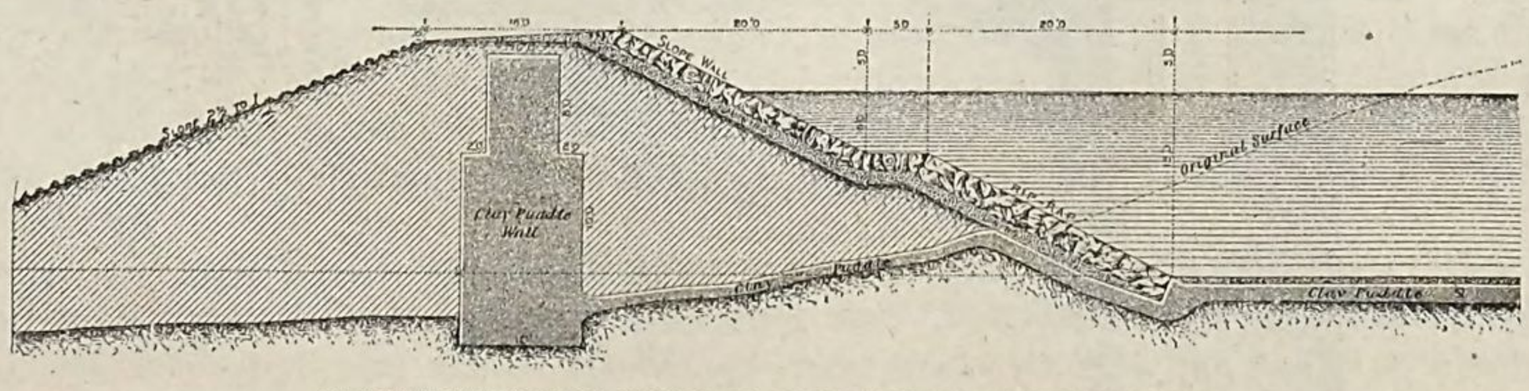
The water is taken from the lake by a wrought-iron pipe, 36 inches diameter, extending 1,000 feet into the lake, its extremity being supported in a timber crib. The latter is 12 feet square and 9 feet high, the sides formed of oak and pine timber 9 by 12 inches, bolted together, and the flooring of oak plank 3 inches thick. A couple of transverse partitions form two compartments, filled with stone to sink the crib. The top of the structure is covered with timbers laid 4 inches apart, to protect the mouth of the pipe from influx of floating materials. The pipe, beginning at one of the compartments in a funnel-shaped mouth-piece, consists of 300 feet of $\frac{3}{16}$-inch wrought-iron pipe laid in lengths of 75, 97, and 100 feet, with ball-and-socket joints. The remaining 700 feet, 36 inches diameter, was laid in a trench in the lake-bottom, wooden platforms being placed beneath the joints in certain soft places to prevent them from sinking too deeply. The inlet-pipe in the crib takes water at a depth of 30 feet below the surface of the lake. The lake itself is a sheet of very soft water 6.7 miles long, $\frac{6}{10}$ of a mile wide, and from 40 to 90 feet deep. Its water-surface is 1,828 acres, and its bed is of Genesee shale. Its drainage area is 42.39 square miles, and its banks are bold bluffs of uncultivated land. Canadice lake, which is also tapped, lying to the east of the Hemlock valley and adjacent to it, is 3.1 miles by $\frac{1}{3}$ mile, and 648 acres in area. It discharges into Hemlock outlet $\frac{1}{4}$ mile from the latter lake. The minimum flow of Canadice lake is estimated at 2,000,000 and that of Hemlock lake at 12,000,000 gallons per day. The head of water between the lake and the distributing reservoir is 261 feet. The main, which follows the profile of the country, is of the following dimensions:

	Linear feet.
36- by $\frac{3}{16}$-inch wrought-iron pipe, to face of gate-house at Hemlock lake	50,776.00
24- by $\frac{3}{16}$-inch wrought-iron pipe	1,913.65
24-inch cast-iron pipe	30,549.75
24- by $\frac{1}{4}$-inch wrought-iron pipe	13,809.38
From face of well-house, 24-inch cast-iron pipe	4,212.27
From inlet-opening in bottom of Rush reservoir to outside face of well-house, 24-inch cast-iron pipe	1,010.00
Total from face of gate-house to inlet-well, linear feet	102,271.05

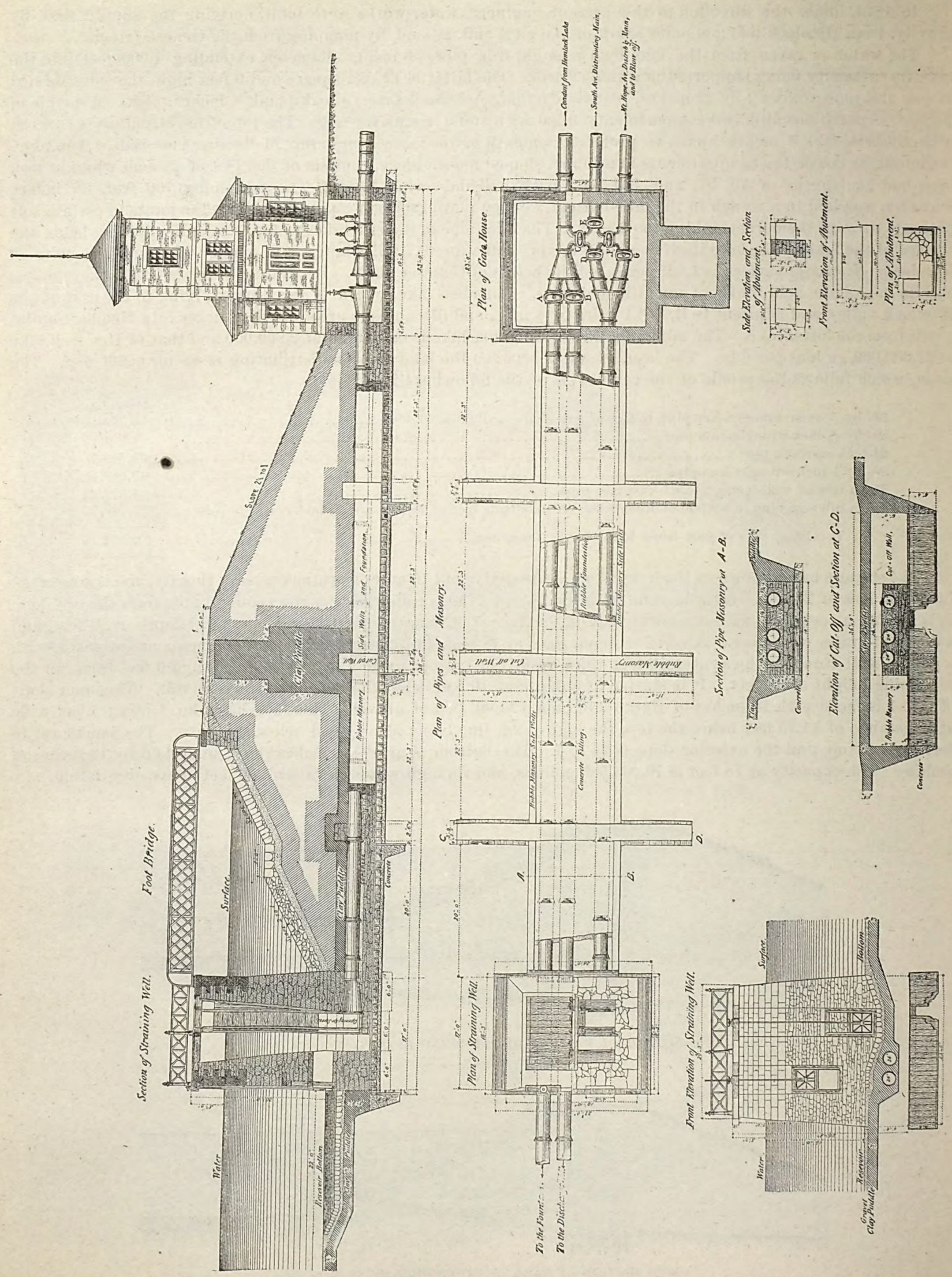
The storage basin known as Rush reservoir is situated about 10 miles from the center of the city, and is connected by 46,064 feet of 24-inch cast-iron main with the Mount Hope or distributing reservoir, $1\frac{3}{4}$ mile from the city hall. It is in plan a rectangle with one corner cut off, having a bottom area of 10.354 acres, a total depth of 24 feet, and a depth of water of 18 feet. Area of water-surface at 18 feet, 13.702 acres. The embankments are of earth, with a puddle-wall through the center 10 feet thick from the bottom up to a height of 8 feet, and 6 feet thick for the remaining height of 12 feet. It is started at a depth of 10 feet below the bottom of the reservoir. The inner slope of 2 to 1 is faced with 18 inches of riprap laid on a 12-inch bed of gravel. This face has a level offset 5 feet wide at a distance of 11.25 feet below the top, the high-water line being also $4\frac{1}{4}$ feet below the same. The banks are 16 feet wide at top, and the exterior slope is $2\frac{1}{2}$ to 1. The bottom is gravel, 8 inches thick, underlaid by 18 inches of puddle. The capacity at 18 feet is 70,033,589 gallons, and its high-water elevation 242 feet above city datum.



CROSS SECTION OF BANK OF DISTRIBUTING RESERVOIR, ROCHESTER.



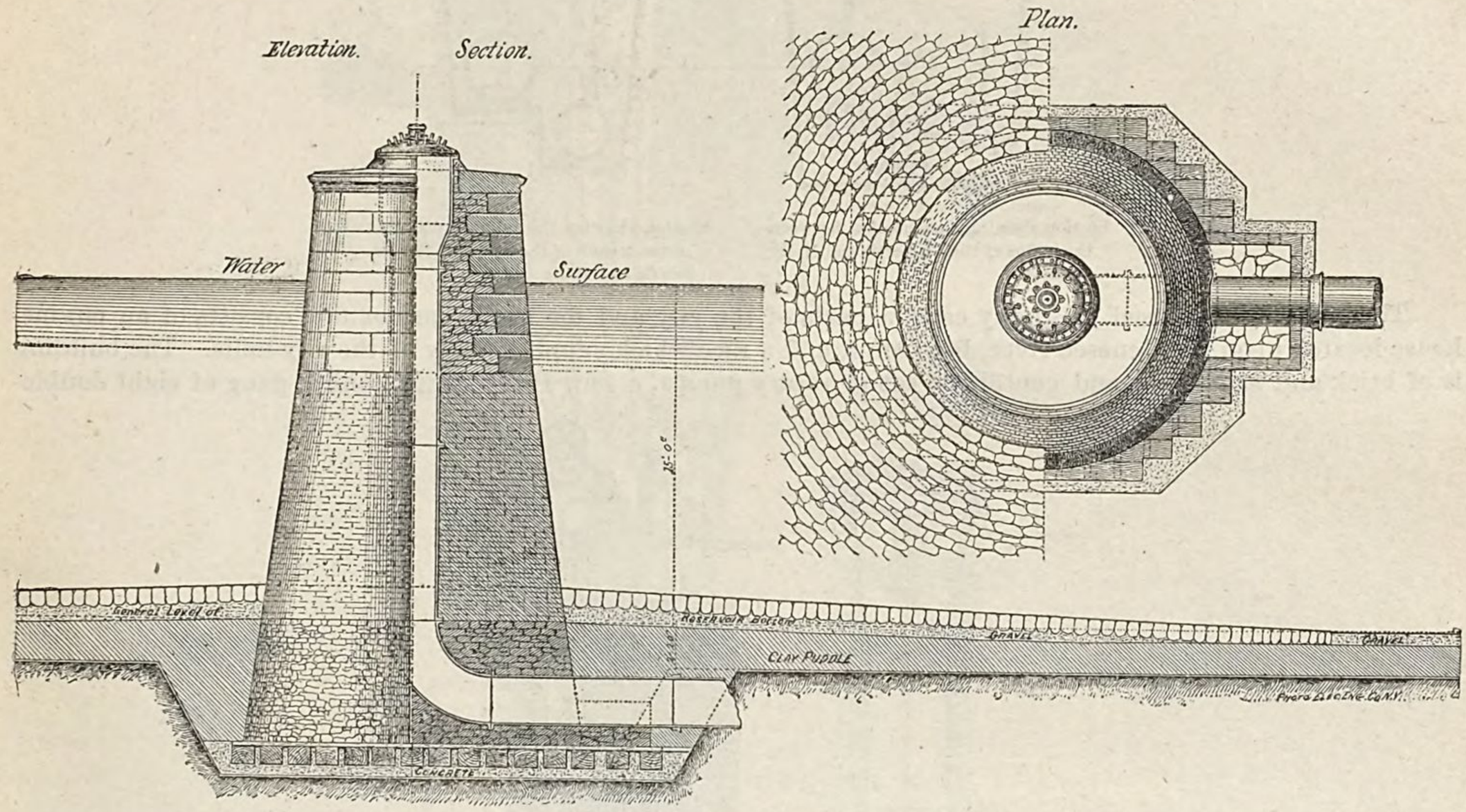
CROSS SECTION OF BANK OF STORAGE RESERVOIR, RUSH.



PLAN SHOWING MANNER OF LAYING PIPES UNDER BANK OF DISTRIBUTING RESERVOIR, ALSO PLANS OF STRAINING WELL AND GATE-HOUSE.

Mount Hope reservoir, 1¾ mile from the city hall, in plan is a segment of a circle with one extremity cut off. Its construction is very similar to that of the Rush reservoir. The bottom area is 3.887 acres, and area of high-water surface 5.517 acres, the depth of the water being 16 feet, and total depth to top of banks 20 feet. Width of banks, 16 feet. Capacity at 16 feet depth, 24,278,101 gallons. Slopes and puddle-wall as before.

The 24-inch main from Rush enters the Mount Hope basin at the center, and rises through a masonry pier to a few feet above high-water surface, where it discharges through a fountain-jet to a considerable height. It is a



PLAN OF FOUNTAIN FOR DISTRIBUTING RESERVOIR.

noteworthy fact in this connection that at a time when the whole city was annoyed by the old familiar "fish-lake odor" in the water-supply the water in this reservoir was entirely free from the taint. This would seem to show that aeration through fountain-jets is an effective cure for this almost universal difficulty, although in many cases it would be a difficult matter to obtain the necessary head.

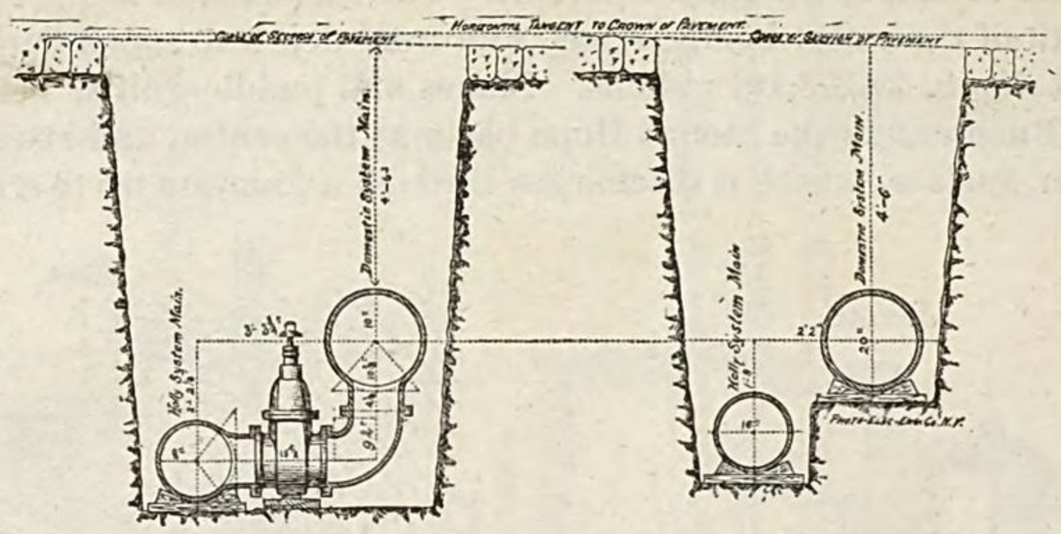
By an arrangement of valves in the supply-mains and pipes, the water from the Rush reservoir may be directly connected with the distribution pipes of the city, and produce a much greater pressure. This operation, which consumes but a few moments, is used to a considerable extent in the suppression of fires, the office and different parts of the works being connected by telephone. The use of this instrument in water-works is very general throughout the country, and has worked remarkable changes in their management. The level of water in the reservoirs is measured from the Erie Canal aqueduct. Water-surface of Hemlock lake is accordingly 388 feet, flow-line of Rush, 241.84 feet, and of Mount Hope, 124.4 feet above this datum.

The effluent-chambers or straining-wells of Rush and Mount Hope basins are in masonry towers rising above water-level at the foot of the slopes and connected with banks by iron foot-bridges. There are two openings from the reservoirs into them, one at bottom for draining and one 8 feet below high water. They are each 3 feet square, closed by a sliding gate from above. Screens of wire, ¼-inch mesh, protect the entrance of the effluent-pipes. The effluent-wells are 6 by 13 feet at bottom by 9½ by 13 feet at top.

For the purpose of utilizing the waters of Canadice lake a bulkhead was constructed at the northern end of the lake, extending across the natural outlet creek, which delivers the water from it into Hemlock lake. It consists of two stone abutments, with an intermediate pier of masonry, forming two channels. Across these are placed stop-planks, provided with sliding gates. The foundation of the water-ways, abutments, and pier are of timber, the upper surface of which is 8 feet below high-water level. Sheet-piling was driven in front and behind its edges. The abutments and pier are of rubble masonry 10 feet high, 22½ feet long, and 4½ feet thick; width of water-ways, 15 feet.

There are twelve openings in each gate, arranged in three tiers of four each. The upper ones are 22 inches wide and 24 inches high, the bottoms being on the highwater line. The remaining tiers contain gates or openings 22 inches wide and 36 inches high, and are all below high-water line, with rack and pinion appliances for raising and lowering them. There are no slides to the upper tier, which therefore act simply as sluices.

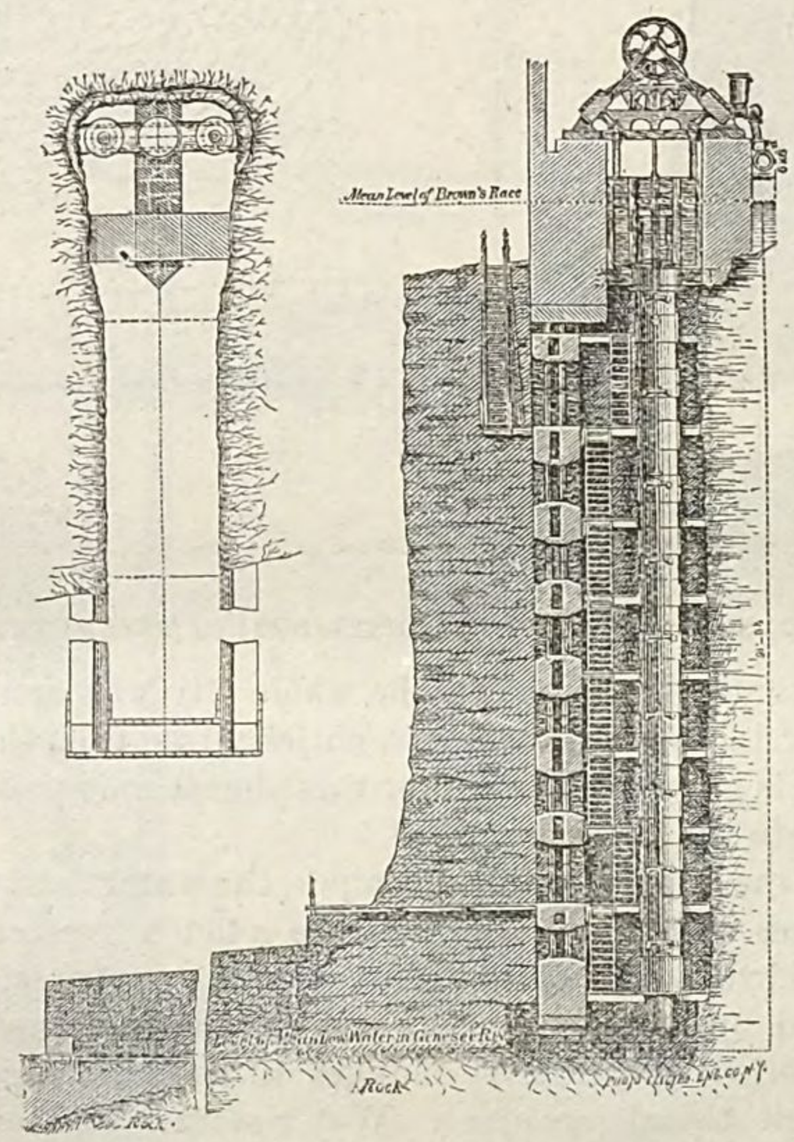
A connection is arranged at different points between the gravity and Holly systems.



Section showing a connection between the mains of the Domestic and Holly systems.

Section showing the relative positions in the trench of the mains of the Domestic and Holly systems.

The Holly system, used to supply certain parts of the city and for use in case of fire, consists of an engine-house located upon the Genesee river, between it and a race which supplies many of the city mills. The building is of brick and sandstone, and contains a set of rotary pumps, a new Holly engine, and a gang of eight double-

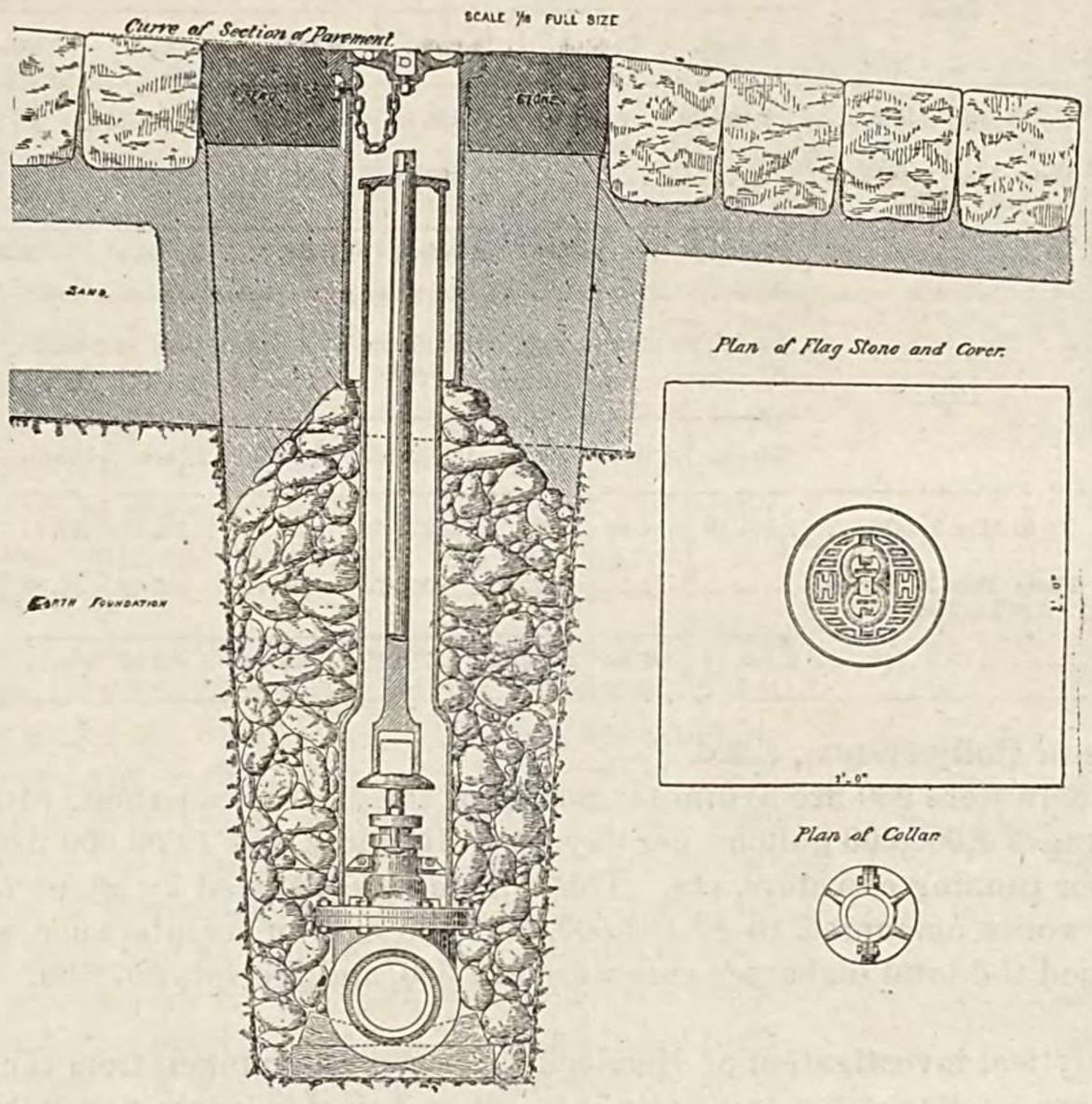


acting pumps. The latter are operated by a pair of Centennial or Tate turbines. The water running them is derived from near the head of the race, and the supply to all the pumps is taken either from a 20-inch main from Hemlock lake or by a 24-inch wrought-iron pipe from the river above the works.

The new engine is at present used only as auxiliary to the others at times. It has four steam-cylinders, 16 inches diameter, 27 inches stroke, operated at high pressure, four double-acting piston-pumps aligned with them, 10 inches in diameter by 27 inches stroke. The speed averages 35 revolutions per minute. It may be used as a condensing-engine.

The rotary pumps, two in number, are so arranged as to be run either by two steam rotary engines or by the engine last described. They run at 200 revolutions per minute, discharging 16 gallons per revolution. The remaining machinery, consisting of two sets of four pumps each, is operated by water-power, with two Centennial or Tate wheels. The latter are 25 inches in diameter, and run, under a head of 90 feet, at from 220 to 600 revolutions per minute. Each set consists of four double-acting pumps, two fastened at an inclination upward on each side of a cast-iron frame, and by means of connecting-rods driven by gear-wheels above. These cylinders are 9 inches diameter and 24 inches stroke. The maximum speed is 40 revolutions per minute. The plungers are of the plain piston type. The capacity of the new engine is 3,000,000, and of the rotary engines and of the water-set 4,000,000 gallons per 24 hours. Water is conveyed to the turbines through a wrought-iron flume $4\frac{1}{2}$ feet in diameter, $\frac{1}{4}$ inch thick.

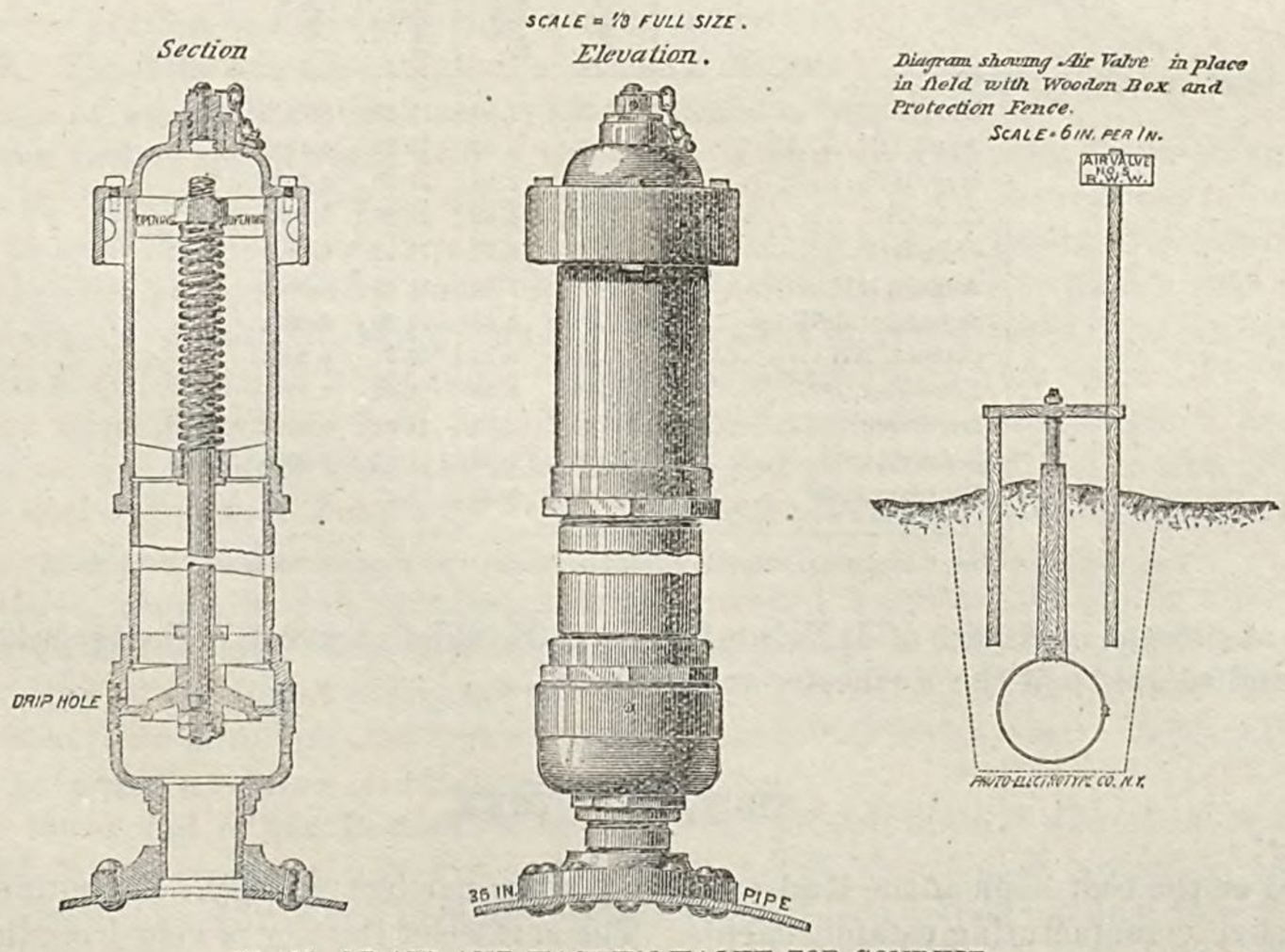
There are three multitubular boilers to supply the large engine with steam. They are 16 feet long by 52 inches diameter of shell, and contain fifty-nine 3½-inch tubes in each. They use anthracite coal, and, with a pressure of 90 or 100 pounds, give a very high evaporation.



PLAN OF CAST-IRON STOP-GATE BOX.

The cost of the wheels, boilers, machinery, penstocks, etc., set up, amounted to $78,000. The average daily pressure maintained by this Holly system is 65 pounds.

The extent of the Holly system mains is about 8 miles in the heart of the city. Details of stop-gates and air-valves are given in the cuts.



PLAN OF AIR-AND-VACUUM VALVE FOR CONDUIT.

The discharging capacity of the conduit from Hemlock lake to Rush reservoir proved by experiment to be 9,293,000 gallons per day. In this section are two grade lines, the first falling 27 feet below lake-level in 51,000 feet, and the succeeding one falling 143 feet in 52,000 feet.

The annexed table contains a general summary of extent of all water-pipes regarded as distributing mains laid in the city:

By whom laid.	Date.	NUMBER OF LINEAR FEET OF CAST-IRON MAINS LAID.							
		24-inch.	20-inch.	16-inch.	12-inch.	10-inch.	8-inch.	6-inch.	4-inch.
Water commissioners and executive board.	Up to May 1, 1879.....	3, 601. 10	8, 293. 30	45, 437. 83	33, 975. 20	10, 005. 31	63, 119. 28	153, 912. 08	171, 355. 60
Water-works and fire board.....	From May 1, 1879, to April 1, 1880.	.....	.....	668. 38	301. 14	851. 65	2, 573. 92	17, 208. 54	23, 550. 32
Total.....	.....	3, 601. 10	8, 293, 30	46, 106. 21	34, 276. 34	10, 856. 96	65, 693. 20	171, 120. 62	194, 905. 92

By whom laid.	Date.	NUMBER OF LINEAR FEET WROUGHT-IRON AND LEAD PIPE FOR MAINS LAID.							TOTAL NUMBER LINEAR FEET LAID IN EACH SYSTEM.		Total.
		3-inch.	2½-inch.	2-inch.	1½-inch.	1¼-inch.	1-inch.	¾-inch.	Domestic.	Holly.	
Water commissioners and executive board.	Up to May 1, 1879.....	2, 864. 00	798. 80	1, 984. 20	5, 213. 51	664. 80	2, 504. 21	341. 02	460, 148. 34	43, 921. 90	504, 070. 24
Water-works and fire board.....	From May 1, 1879, to April 1, 1880.	.....	.....	172. 31	561. 70	659. 05	298. 69	67. 00	46, 704. 96	207. 74	46, 912. 70
Total.....	.....	2, 864. 00	798. 80	2, 156. 51	5, 775. 21	1, 323. 85	2, 802. 90	408. 02	506, 853. 30	44, 129. 64	550, 982. 94

Total number of miles in Holly system, 8.326.

Up to April 1, 1881, there were 980 fire-hydrants, mostly of the Matthews patent, with a few Ludlow.

The consumption averages 4,500,000 gallons per day from Hemlock and 1,000,000 from the Holly system, the latter being used mostly for running elevators, etc. This amount is consumed by about 7,800 takers.

The first cost of the works amounted to $3,182,000, and the cost of maintenance and repairs for 1879 was $33,184. In the same period the total disbursements were $74,846, and receipts $67,000. About 125 meters are in use at the present time.

The results of an analytical investigation of Hemlock Lake water, as taken from the mains of the city, made by Professor S. A. Lattimore, of Rochester university, are given below in parts per 100,000 of water by weight, and grains per United States gallon:

Date.	SOLID RESIDUE.			"Albuminoid ammonia."
	Inorganic.	Organic and volatile.	Total at 212° Fahr.	
March, 1877.....	7. 25	4. 00	11. 25	0. 0005
April, 1877.....	7. 25	3. 95	11. 20	0. 0005
May, 1877.....	7. 22	3. 98	11. 20	0. 0005
June, 1877.....	7. 22	4. 03	11. 25	0. 0004
July, 1877.....	7. 23	3. 92	11. 15	0. 0005
August, 1877.....	7. 20	3. 80	11. 00	0. 0002
September, 1877.....	7. 25	3. 65	10. 90	0. 0004
October, 1877.....	7. 20	3. 75	10. 95	0. 0002
November, 1877.....	7. 15	3. 85	11. 00	0. 0005
December, 1877.....	7. 20	3. 80	11. 00	0. 0002
January, 1878.....	7. 22	3. 73	11. 05	0. 0005
February, 1878.....	7. 20	3. 85	11. 05	0. 0005

Total solids, residue, 6.40 grains; chloride of sodium, trace; "albuminoid ammonia," 0.001 grain.

The works are at present in charge of J. Nelson Tubbs, C. E., chief engineer. The records, including drawings, are unusually full and complete at the Rochester water-works.

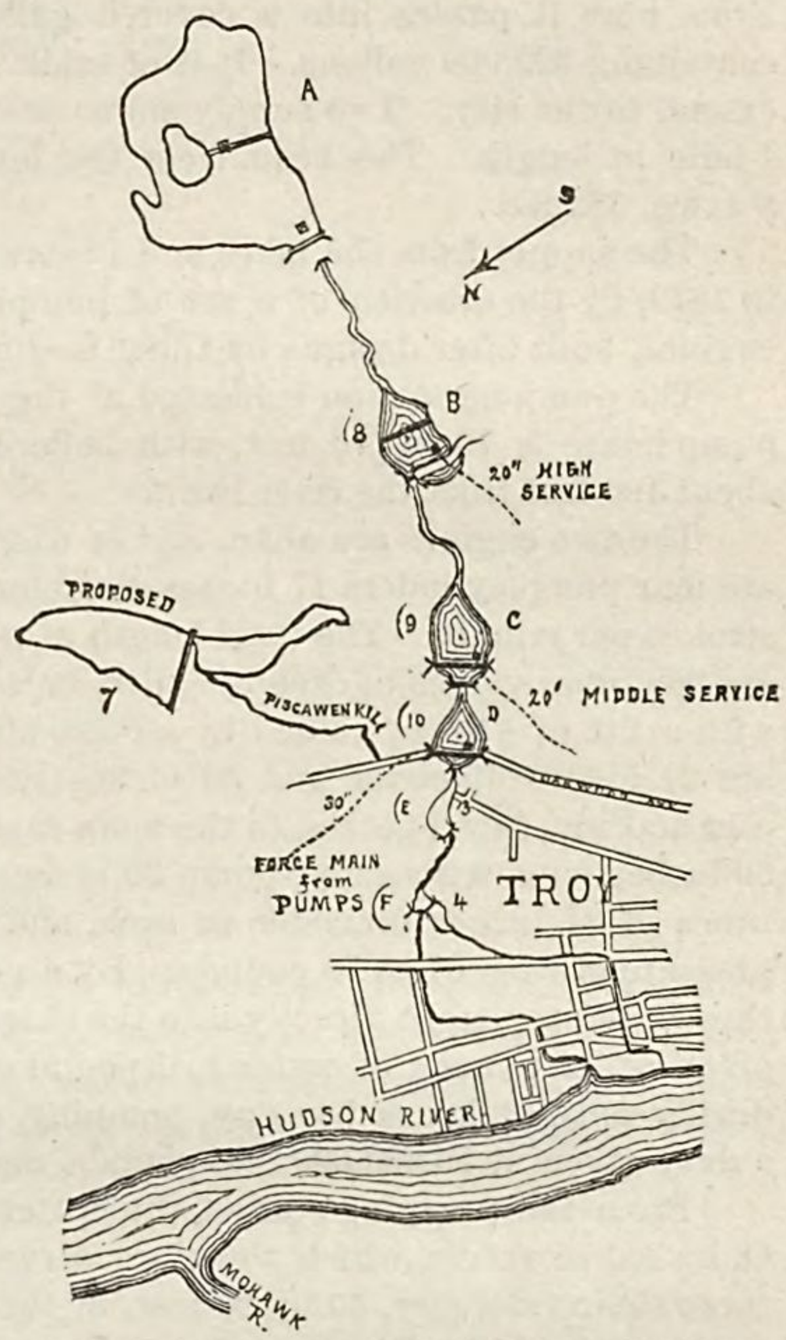
TROY, NEW YORK.

Troy is situated on the east bank of the Hudson river, 6 miles north of Albany. It contains 56,747 inhabitants, and has very extensive manufacturing establishments. The surface of the city is very irregular, with sections of it elevated to a height of from 100 to 200 feet above the rest. The larger portion of the city, however, is but little elevated above high water in the river. The streets are laid out rectangularly with considerable regularity.

Water was first introduced into the city by gravity in 1833 by a private corporation, but the works, since 1855, have been controlled by the city. As at present existing, the system is a combination of direct pumping and gravity. The former is accomplished by a system of Holly pumping machinery, and the latter is derived from three reservoirs on Piscawen creek, 1 mile east of the Hudson river, numbered 8, 9, and 10 on the accompanying map. The total drainage area of these ponds is 1,900 acres, with an average annual rainfall of 39 inches, the range being from 30 to 42 inches.

The first storage or impounding reservoir (No. 9) is located about 50 rods east of Oakwood avenue, in the bed of the Piscawen creek, and is formed by backing up the water behind an earth dam 35 feet long by 165 feet wide at the bottom in the lowest part of the ravine, 20 feet wide by 270 feet long on the top; 35 feet deep at its deepest part near the outlet-pipe, with an average depth of from 15 to 18 feet, and a capacity of 40,000,000 gallons; slope of the embankments, 2 to 1 on the face and 1½ to 1 on the back; water-line 5 feet below the top of the banks. The greatest height of the bank is 49 feet. A puddle-wall extends through the center of the bank 15 feet thick from the base to a height of 12 feet, 13 feet thick for the next 10 feet, 11 feet thick for 10 feet above, and finished to within 2 feet of the top at a thickness of 8 feet. The base of the dam rests upon a foundation of slate-rock, which underlies this whole section of country. It was started in a trench 15 feet wide by 6 feet deep.

Three cast-iron pipes—two 12-inch and one 8-inch—extend from the foot of the inner slope through the embankment, a distance of 140 feet, to the pipe-chamber under the outer slope. It is a stone chamber arched with brick, 16 feet long, 9 feet high, and 8 feet wide. The bottom is 2 feet below the outlet. Gates are fitted in the effluent-pipes mentioned, and controlled on the inner side of the chamber at one end. The foot of the outer slope is shortened and backed with a retaining-wall 11 feet high, 36 feet long, and 4½ feet thick, in which doors and a passage-way lead to the pipe-chamber. The face of the dam is covered with gravel 2 feet thick and riprapped 1½ feet thick. The area of high-water surface is about 8 acres. A waste-weir cut in the rock about 50 feet south of the dam extends around and is entirely disconnected from it, discharging into the creek 200 feet below the dam. The flow of the creek at the dam is about 1,500,000 gallons per day. Cost of reservoir, $16,571.



MAP OF WATER-SUPPLY OF TROY, N. Y.

In 1860–'61 a second reservoir was constructed at (10) (see map) by the erection of a second dam, the back-filling of which forms the embankment of Oakwood avenue, and serves to collect the overflow from the upper dam, No. 9. The dam extends across the ravine a distance of 300 feet. It consists of an earth embankment with a puddle core, started 6 feet below the bed of the stream, with a thickness of 20 feet, gradually diminishing to 6 feet thick at top of the embankment, increasing 2 feet in thickness for every 6 feet in depth from the top by steps. The total height of the dam is 43 feet; slope of inner face 2 to 1, and of outer 1½ to 1; capacity of reservoir, about 40,000,000 gallons. A culvert, 6½ by 6 feet, extending under the avenue, conducts the water from a well on the upper side of the embankment through the dam to the supply-mains. The well is of brick, 4 feet thick at bottom, 2½ feet at top, and 22 by 20 feet, with a partition-wall 2 feet thick. The top is covered by a gate-house 10 by 12 feet. The gates, four in number, on the front side of the well, are of iron, operated by hand-wheels above, except the lower one, which is of heavy timber, and removed only when cleaning the bottom of the well. The iron gates are each 2 by 2½ feet. The top of the well serves as a waste-weir. One of the compartments is 12 by 8 feet, and the other 12 by 4 feet. Total cost of reservoir, $29,312.

There are two lakes, known as the Brunswick lakes, situated 3 miles back of the reservoir described, and having dams for controlling the flow. The area of the upper of the two is about 20 acres water-surface, and of the lower 7 acres, the capacity of the former being about 180,000,000 gallons. They are separated by a dam across the middle. The water from them flows into the Oakwood reservoir through the creek. A storage reservoir, holding 76,000,000 gallons, is proposed as shown on the map at (7).

The dam at the lower end of the Brunswick lakes is very similar to that described as adjoining Oakwood avenue in the lower Oakwood reservoir. It is of earth, puddled, 125 feet thick at bottom by 16 feet at top.

A brick culvert, 125 feet long by 4 feet diameter, passes through the foot of the dam into the stream below. A well, rising on the inside of the dam, forms the only outlet. It is 18 by 20 feet, with 4-foot walls, and divided by

a 2-foot division-wall. On the front of the well are four gates, as before described, each 20 inches square. The dam is 30 feet high, and the reservoir averages 20 feet deep.

The distributing reservoir is shown at (4), and is constructed in a manner very similar to the others, by damming the lower end of a small pond in the bed of the outlet from the Oakwood reservoirs. The bottom and sides are of slate-rock, and a small stone dam, a short distance above the reservoir, is built, 7 feet thick at bottom by 5 feet 7 inches at top; 17 feet high and 67½ feet long. A length of 9 feet in the center is 7 feet thick, and through this part pass two 20-inch pipes, one above the other, and controlled by gates. This dam makes a pond above it, 141 by 25 feet by 5 feet deep, and holding 123,700 gallons. From here the water passes into an excavated reservoir 116 by 67 feet by 8 feet 3 inches deep, containing 450,000 gallons. Another dam below the last carries the water from here through it to a third division, 51 by 41 feet by 8 feet 3 inches deep, containing 115,300 gallons. From here it passes into a covered gallery 304 feet long by 18 feet 4 inches broad by 8 feet 3 inches deep, containing 322,000 gallons. It is of brick, and contains wire screens at its lower end, from which the supply-mains extend to the city. Two supply-mains are in use, one 20 inches in diameter and the other 12 inches, of cast iron, 1 mile in length. The head from the lower service is 105 feet; from the middle, 292 feet; and from the upper service, 382 feet.

The supply from the lakes and Piscawen creek having proved insufficient, it was determined to supplement it, in 1879, by the erection of a set of pumping-machinery. The result was the introduction of two Holly pumping-engines, built after designs by Chief Engineer D. M. Greene, of the Rensselaer Polytechnic Institute.

The pumping-station is located at the northern end of Lansingburg, and below the Waterford bridge. The pump-house is 70 by 70 feet, with boiler-house 40 by 60 feet and coal-shed 60 by 50 feet attached, and situated about 100 feet from the river-bank.

The two engines are alike, and of 6,000,000 gallons capacity. The description of one serves for both. There are four pump-cylinders 17 inches diameter, with plain piston-plungers, and a stroke of 36 inches, making 30 single strokes per minute. The total length of the cylinders is 48 inches, leaving 6 inches clearance at each end. There are 208 brass valves in each cylinder, half in the inlet and half in the outlet. They are circular, 1¾ inch diameter, with a lift of ⅜ inch, guided by a brass stem or spindle, and seating themselves by gravity. The steam-cylinders are 27 inches diameter and 36 inches stroke, with balanced double-beat puppet-valves, operated by an eccentric cam and rod, bevel-geared to the main shaft. The steam is condensed by a jet-condenser 48 inches diameter and 30 inches long, with an air-pump 30 inches diameter and 30 inches stroke. Six multitubular boilers, containing 58 tubes of 3½ inches diameter in each, and 5 feet diameter by 17 feet 4 inches length of shell, supply steam at a pressure of from 67 to 70 pounds. By a peculiar arrangement of dampers the heat beneath all the boilers can be thrown in an instant directly into the chimney, so as to stop the production of steam. The evaporative power is given at 12 pounds of water to 1 pound of anthracite coal used. The pumping-engines are run alternately and during only 12 hours per day, pumping, at 15 revolutions per minute, 3,000,000 gallons into the reservoir, with a duty given at 85,000,000 foot-pounds, and guaranteed by the Holly company at 80,000,000 foot-pounds.

From the pumping-station the water is forced through 3⅓ miles of 30-inch cast-iron main into the lower Oakwood reservoir, which therefore serves as a distributing basin. The water is drawn from the Hudson river through an inlet-pier, 50 by 20 feet, in the river, with well 6 by 6 feet, and a 7½- by 4½-foot tunnel leading from it to the pump-well. The contract price for the complete construction of this branch of the Troy works was $235,000. This includes the costs of the pump-house, boiler-house, and chimney, complete, inlet-chamber and tunnel, two engines, and all appendages, a high-service reservoir, and 3⅙ miles of 30-inch force-main. In addition, there was a stone dock or front at the pumping-station, 300 feet long, at an additional cost of $8,000.

The additional reservoir is built upon the Piscawen creek, in Brunswick, a short distance to the east of the upper Oakwood reservoir, at a cost of $10,000, with a capacity at 6 feet below high water of 2,000,000 gallons. Length of earth dam, 300 feet; maximum height, 20 feet, with a dam forming two compartments, and 100 feet long by 10 feet high, with spill-way 64 feet long. The gate-house is about 16 feet square.

From this reservoir a 20-inch cast-iron main supplies the highest portions of the city, with a maximum head of water equal to 382 feet. The upper Oakwood supplies the districts lying midway between the lowest and highest by a 20-inch main, as before, with a head of 292 feet, while the lower Oakwood allows all its water to pass into the distributing gallery before described (No. 4, see map), and from thence flows with a head of 105 feet through a 12-inch main to supply the lower portions of the town. The total length of distributing mains, with which the above three supply-mains connect, is $38\frac{3420}{5280}$ miles (1880), of 20, 16, 12, 10, 8, 6, and 4 inches diameter, all cast iron. Upon this system of pipes there are 392 Knickerbocker hydrants, made by the Mohawk & Hudson Manufacturing Company, and 563 gates. The consumption averages 4,500,000 gallons, and is supplied to everybody who requests a service, the cost of maintenance and repairs being defrayed by a general tax. Nearly 2,000,000 gallons per day are supplied by the gravity works, the remainder, about 3,000,000 gallons, being pumped.

The first cost of construction of the works was about $216,000, which has been increased to a total in 1880 of $840,000. The annual cost of pumping for 1880 is about $13,000, while the total cost of maintenance and ordinary expenses of the whole works will average $39,000.

The purity of the water from the different sources can be judged from the following analyses made in the analytical laboratory of the Rensselaer Polytechnic Institute in 1872:

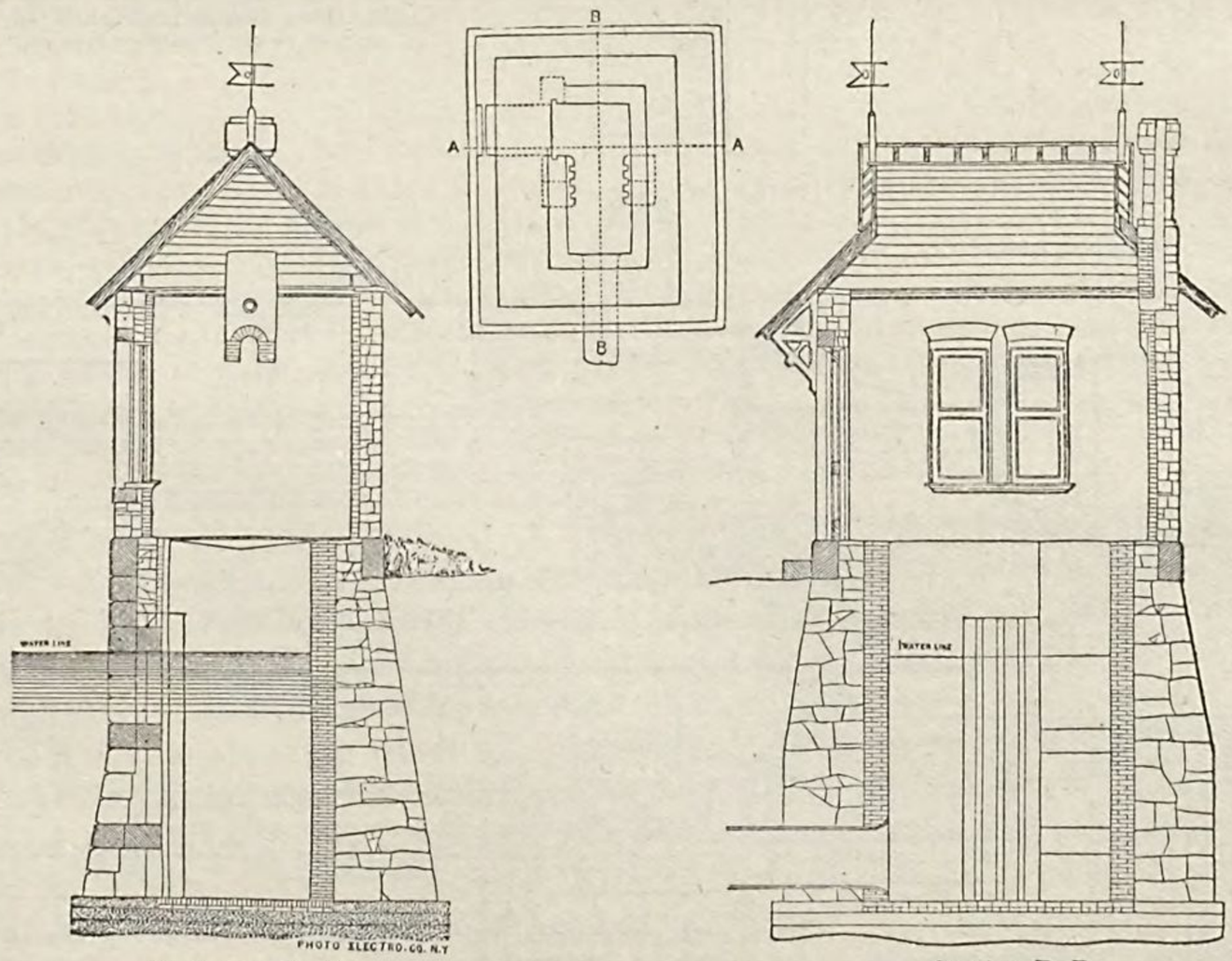
	Reservoir.	Hudson river.
Color in one-foot tube	Slight yellow.	Greenish-yellow.
Taste at 30° C. (86° F.)	None.	Boggy.
Hardness on Clark's scale	7. 4°	3. 16°
	Grains.	*Grains.*
Oxygen absorbed by organic matter from permanganate of potash.	0. 0784	0. 2884
Inorganic matter	6. 6080	3. 7128
Organic matter	1. 8480	1. 4840
Total solids	8. 4560	5. 1968
The inorganic matter contains the following:		
Chlorine	0. 0490	0. 0740
Sulphuric acid, SO_3	0. 2686	0. 2398
Silica	0. 5278	0. 5684
Lime	2. 9801	1. 1409
Magnesia	0. 1551	3. 5940
Oxide of iron, alumina, and phosphates	0. 0210	0. 0266
Potassa	0. 1414	0. 0546
Soda	0. 2079	0. 1204

The water from the river proves softer than that in the creek. The latter was taken from the lower Oakwood reservoir, and that from the river was obtained from near the pumping-station.

The works are under the charge of Professor D. M. Greene, of the Rensselaer Polytechnic Institute, as chief engineer.

PAWTUCKET, RHODE ISLAND.

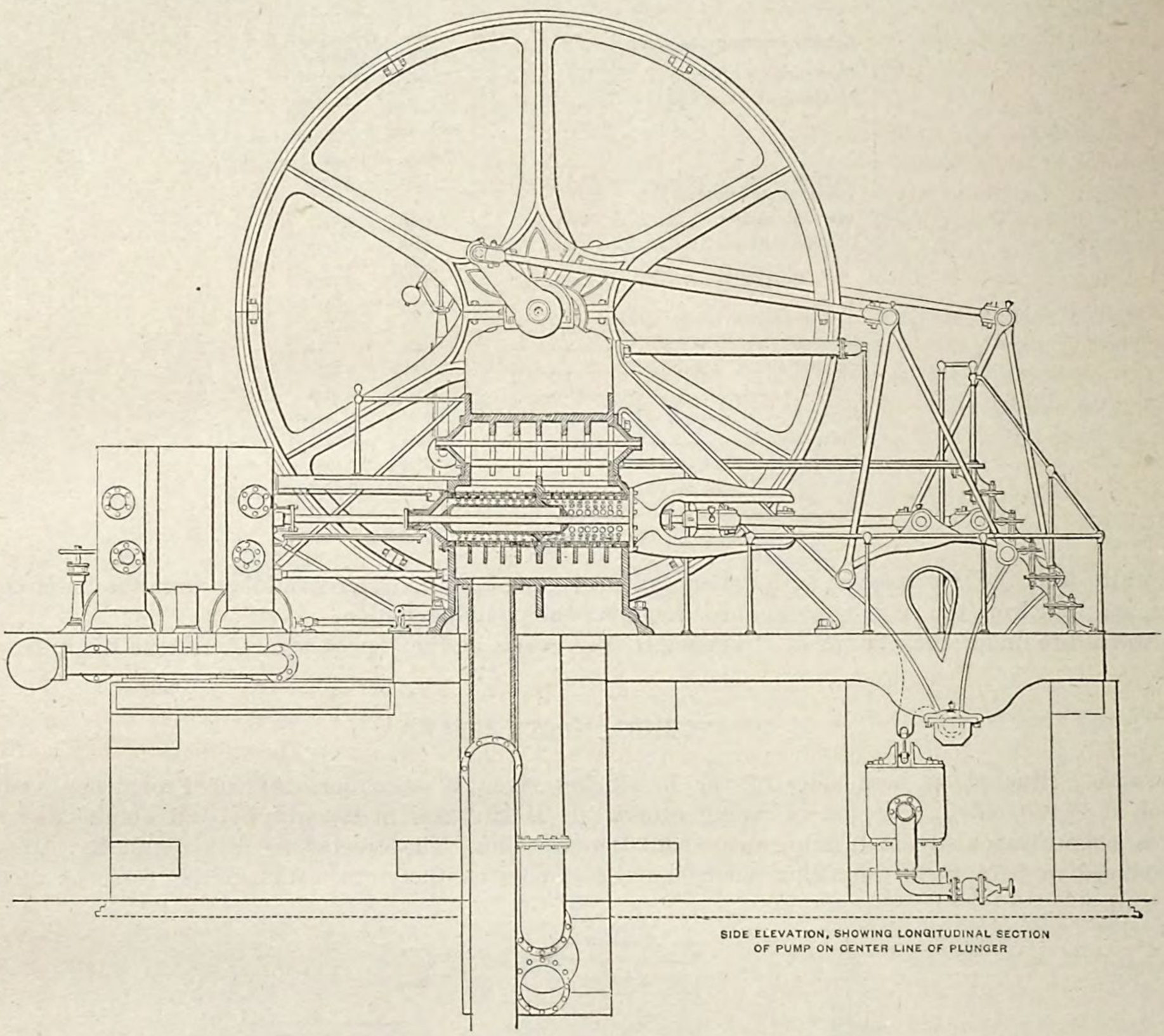
Pawtucket, situated on both sides of the Pawtucket river, 4 miles northeast of Providence, contains a population of 19,030, chiefly engaged in manufactures. It is irregular in topography, and obtains its supply of water from Abbott Run, a stream draining an area of 26 square miles. The streets have little regularity. The supply was introduced in 1878, under municipal control, and is pumped either into a distributing reservoir or directly into the mains.



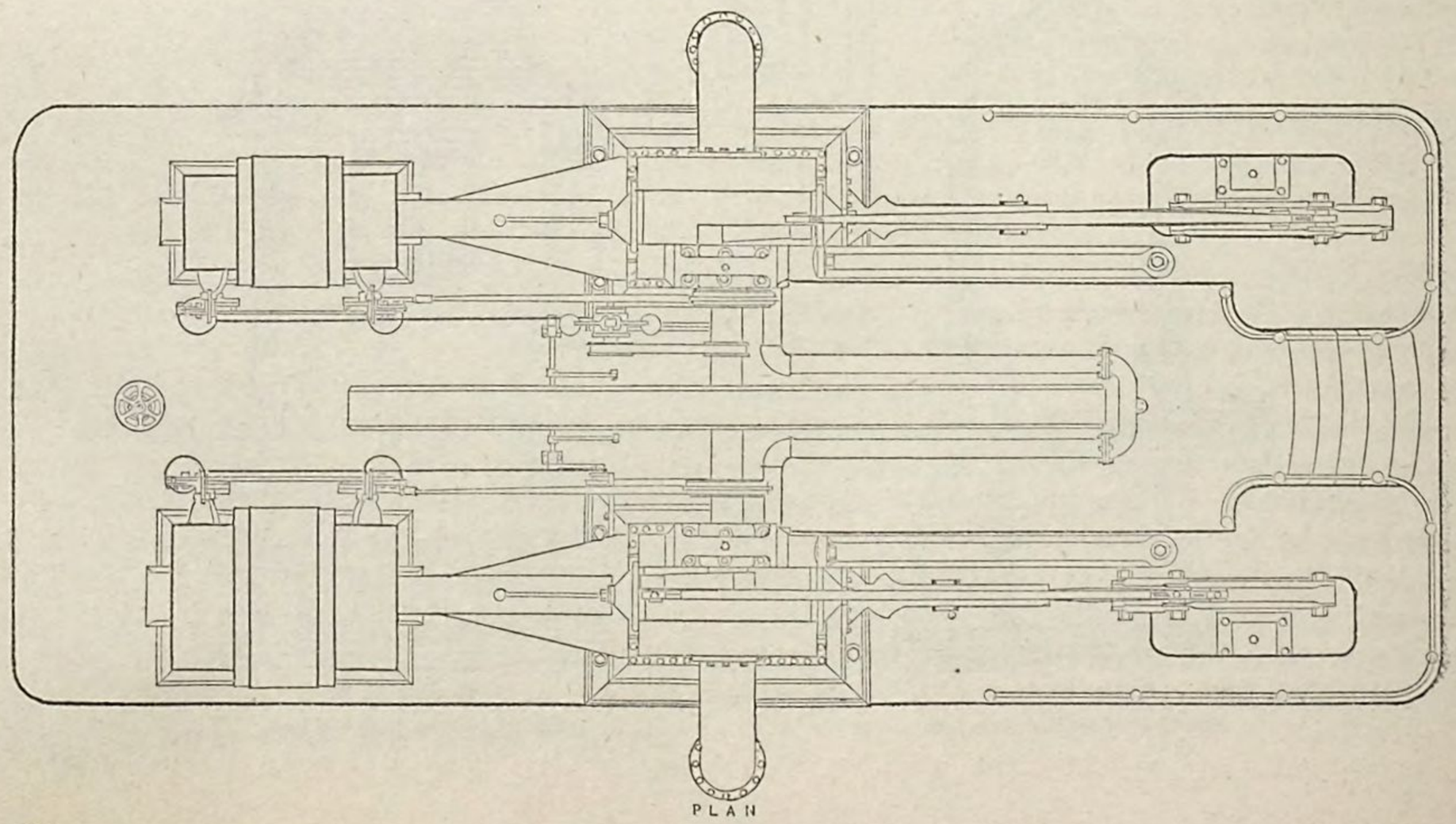
Section on A. A.
Scale 3-16 of an inch to a foot.

Section B. B.
Scale 3-16 of an inch to a foot.

The dam on Abbott Run is a plain wooden structure, 75 feet long and 9 feet high, formerly part of an old water-privilege, upon which a gate-house was constructed at a cost of $5,000. This backs the water into what is known as Happy Hollow pond, having an area of 23 acres and a capacity of 72,000,000 gallons. The water, passing through three sets of screens in the gate-house, shown in the cut, enters a 30-inch cast-iron conduit 3,696 feet long,



SIDE ELEVATION, SHOWING LONGITUDINAL SECTION OF PUMP ON CENTER LINE OF PLUNGER



PLAN

to the engine-house. The pump-well is 10 feet in diameter and 17 feet deep, containing about 14 feet of water. The pumping-station is of brick and stone, 40 by 45 feet, with a wing 25 by 30 feet, and one of the handsomest in the country. The pumping-engines, built by George H. Corliss in 1878, are compound condensing-engines, two being coupled to the same fly-wheel, the principal dimensions of which may be seen from the appended description:

Diameter of high-pressure cylinder	inches	15
Diameter of low-pressure cylinder	do	30
Diameter of piston-rods	do	2½
Length of stroke	do	30
Diameter of pump-barrel	do	15
Diameter of plunger	do	10.52
Diameter of plunger-rod	do	2½
Diameter of suction- and discharge-pipes	do	15
Diameter of fly-wheel	feet	18

Each pump is a double-acting plunger-pump, and contains 280 Corliss copper disk-valves, 2 inches in diameter each, with a free lift. These valves consist of a single disk of sheet copper, the top of which is attached to a flat spiral spring, the upper end of which is fixed. They rest upon their seats with the elasticity of rubber, the only effect of time appearing to be that they fit, if possible, more perfectly to their seats.

Steam is supplied by three vertical multitubular boilers, the dimensions and particulars of which are given below:

Number of boilers		3
Length of shell	feet	14
Diameter of shell	do	4
Height of fire-chamber	do	3½
Number of tubes		48
Diameter of tubes	inches	3
Grate-surface	square feet	19.63
Fire-surface	do	560
Average steam-space	feet	3½ to 4
Average steam-pressure	pounds	125
Average water-pressure	do	110

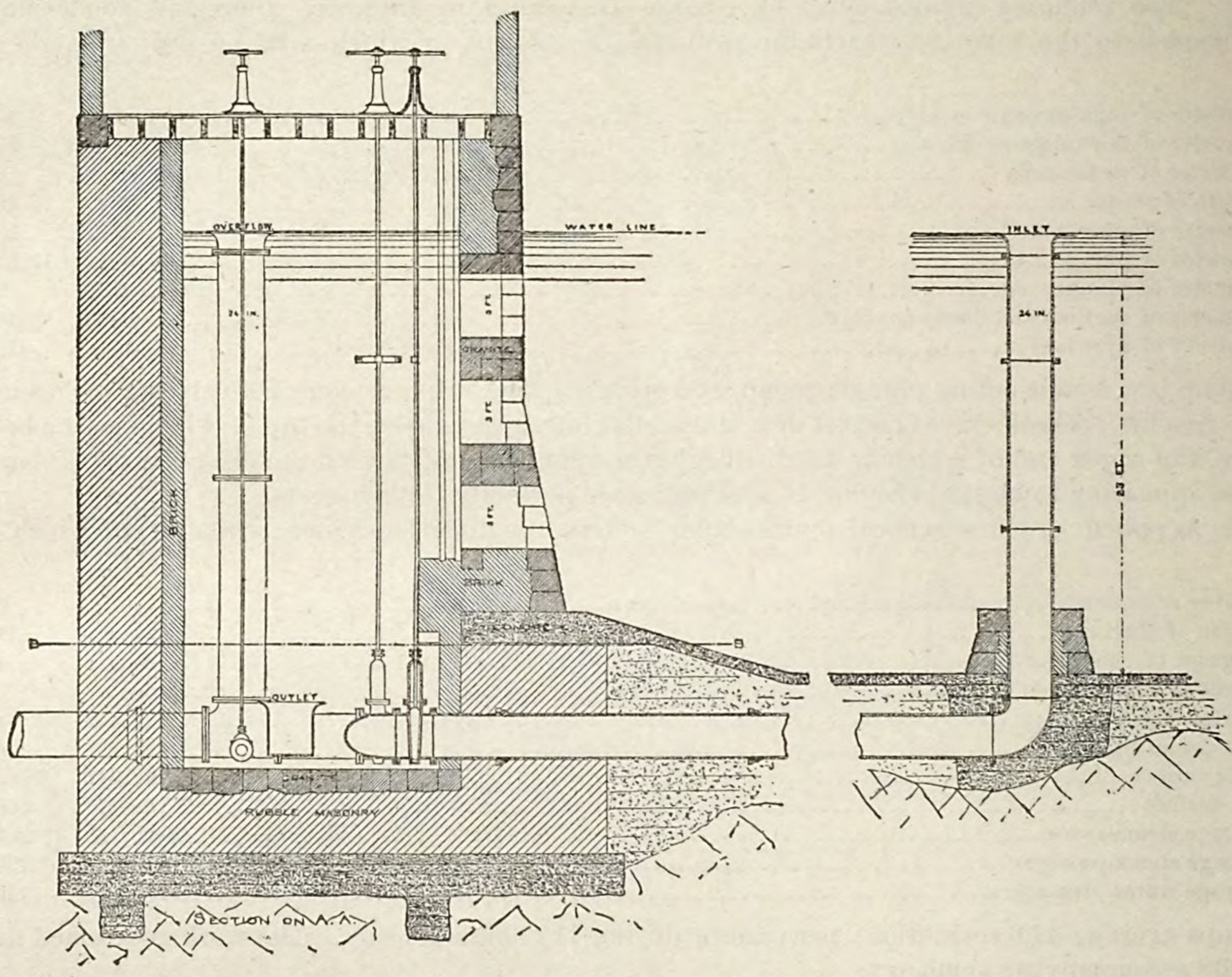
The pumps average 44.6 revolutions per minute during 11½ hours per day. The work performed during 1879 is given in the accompanying summary:

Number of days' pumping		252
Total pumping time per month, in hours and minutes		247 29
Average pumping time per day, in hours and minutes		11 59
Total revolutions per month		7,956,727
Average revolutions per minute		44.61
Coal consumed starting fires	pounds	178,375
Coal consumed pumping	do	471,441
Coal consumed banking	do	57,800
Coal consumed heating building	do	29,133
Total coal consumed	do	736,749
Total number of gallons pumped per month		325,408,303
Average number of gallons pumped per pound of coal consumed, excluding heating when not pumping		458.42
Average number of gallons raised 100 feet per pound of coal consumed		1,200.50
Average head against pump, in feet (no allowance for friction in suction)		262.30
Average duty in pounds of water raised 1 foot high per 100 pounds of coal (calculated on total coal used for all purposes; no deduction for ashes and cinders)		96,046,816
Average duty in pounds of water raised 1 foot high per 100 pounds of coal (calculated on amount of coal used for starting, pumping, and banking; no deduction for ashes and cinders)		105,014,399

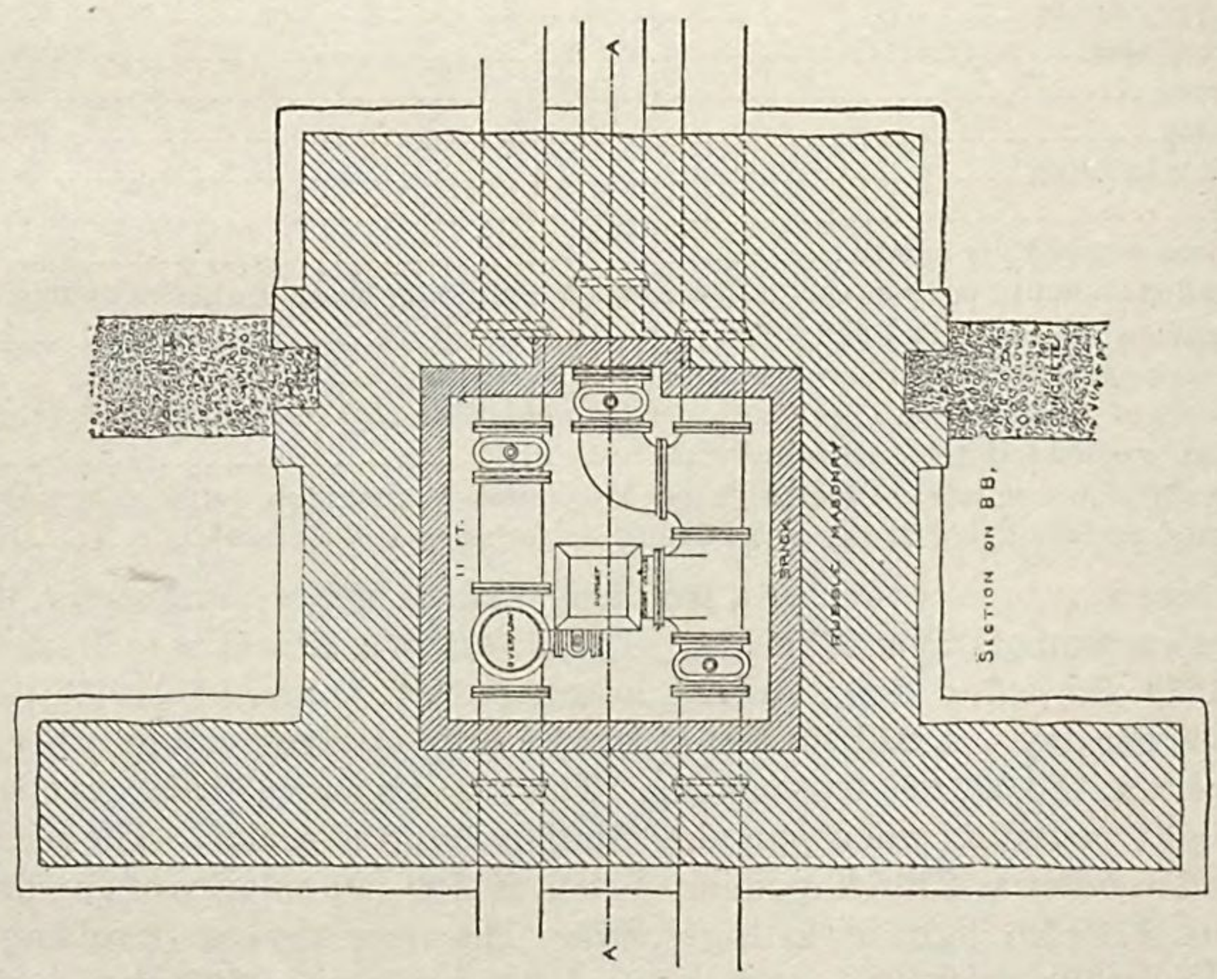
Condensation takes place in a pipe-condenser 6 feet long and 10 inches in diameter, the water being injected at one end and producing a vacuum of 26½ or 27 inches. The air-pump is 20 inches in diameter and 7¼ inches stroke. The test trial made in 1878 showed a duty, during a run of 120 hours, of 104,357,654 foot-pounds, with a capacity of 3,060,000 gallons per day. A 24-hour test showed a duty in excess of any other encountered among the water-works of the country, viz, 133,522,060 foot-pounds. The engines cost $30,000, erected. The rate of speed is so high as to produce a slight pounding when pumping directly into the mains. The pumping expenses for 1880 amounted to $4,419, divided as follows: 736,749 pounds of coal, $1,790 59; salaries of engineers, firemen, watchmen, etc., $2,460; oil, waste, etc., $118 50; lighting with gas, $50. Therefore the cost of raising 1,000,000 gallons 1 foot high is 5⅙ cents. From the engine-house the water is forced through a main 24 inches in diameter and 11,000 feet long, into the distributing reservoir, under a total head of 269 feet.

This reservoir is 300 feet above tide-water, with an area of 3 acres, circular in plan, and a capacity of 20,000,000 gallons. Its depth is 21 feet. The embankments are of earth, resting on a natural ledge of rock, faced with masonry on the inner side, behind which are 2 feet of concrete; this masonry facing rests on 6 feet of concrete, and

a layer of 12 inches of the same material extends over the whole reservoir bottom. The top of the embankment is 35 feet wide with an outer slope of 1½ to 1. Further details can be seen from the figure. A section of the gate-house is also given.



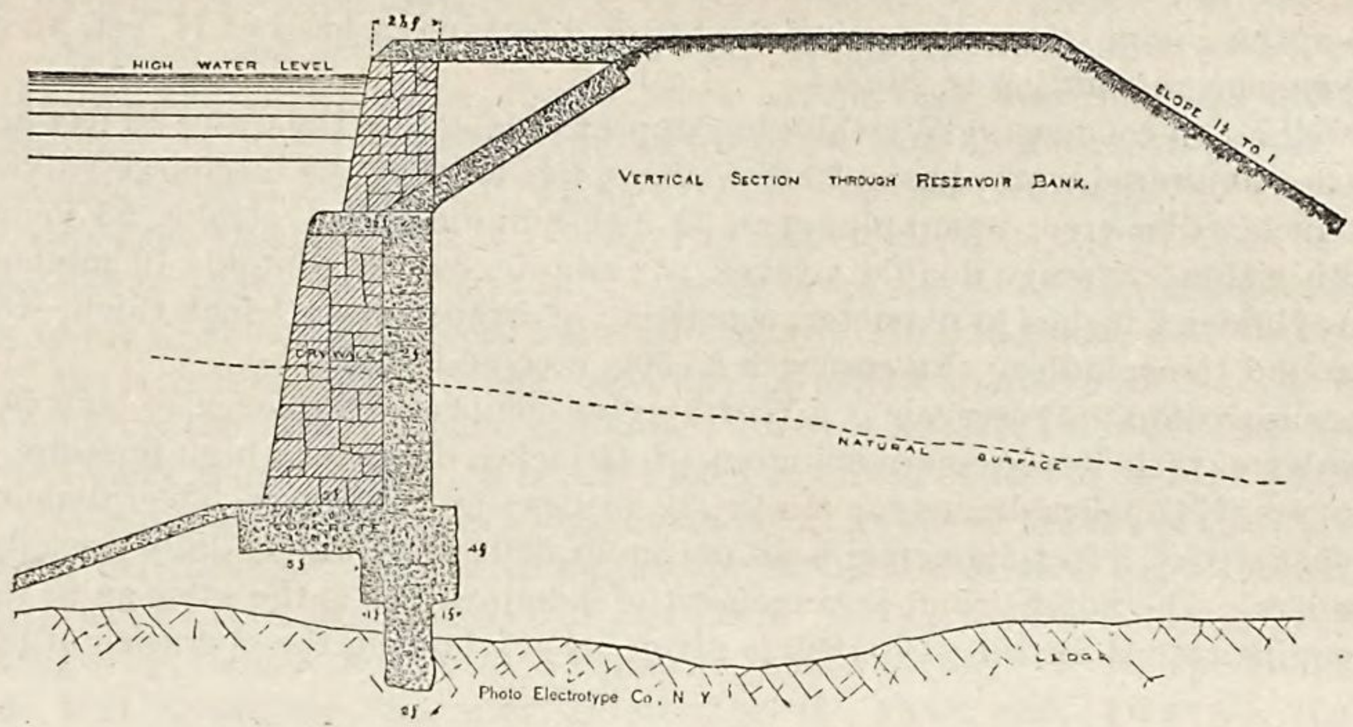
When the engine begins pumping, a check-valve in the gate-house closes and the water flows into the reservoir through the stand-pipe near the center; when it ceases, the same valve opens and the water flows back to the town through the gate-house. It will thus be seen that any surplus above the consumption flows into the reservoir for storage.



There are three gates, each 3 feet square, entering the inlet-chamber for the purpose of drawing the water from different depths.

A receiving basin was partly completed to hold about 7,000,000 gallons, and located in the immediate vicinity of the pumping-station. It was designed to be used as a reserve in case of accident to the conduit or a turbid state

of the water, or to receive the overflow of the conduit in case of a freshet at the dam. It might be well here to state that the engine is situated at one end of the town and the reservoir at the other.



The total amount of pipe laid is 30.59 miles, as follows: 30-inch, 3,696 feet; 24-inch, 10,994 feet; 20-inch, 8,928 feet; 12-inch, 13,327 feet; 10-inch, 13,787 feet; 8-inch, 36,098 feet; 6-inch, 44,248 feet; 4-inch, 30,449 feet. They are of cast iron, coated inside and out with cold-tar varnish; 472 fire-hydrants are in use (of the Fales & Jenks pattern), placed from 250 to 500 feet apart. Of service-pipe there is about 66,500 feet of 2 inches, 1½ inch, 1¼ inch, 1 inch, and ¾ inch in diameter, of wrought iron dipped in coal tar; 1,065 Union rotary meters are in use, giving great satisfaction.

The consumption averaged 891,529 gallons per day during 1880, supplied, by the pumps working a little over 11 hours per day, to 2,043 consumers.

There is probably less waste of water in Pawtucket, in proportion to its size, than in most cities in the country.

The total cost of the works to April, 1880, amounts to $608,071, although not then quite completed. The annual cost of maintenance for the year ending April 1, 1881, amounted to about $8,497. The receipts from April 1, 1880, to February 1, 1881, amounted to $23,000. No analysis of the water seems to have been made. The present superintendent is Mr. Edwin Darling, and the management is by a board of three commissioners.

POUGHKEEPSIE, NEW YORK.

Poughkeepsie, containing a population of 20,207, is situated on the east bank of the Hudson river 75 miles from its mouth. From the river-bank the site of the city slopes abruptly for about 1 mile eastward. Back of this is a comparatively level plateau at an elevation of about 250 feet above the river-level, at which point the streets are regular. Its business interests are chiefly commercial and manufacturing. On account of the failure of the old gravity works, a new supply of water was introduced in 1872 from the Hudson river at a point about 1½ mile above the city, and under the auspices of the city authorities and the direction of Mr. James P. Kirkwood, civil engineer.

At this point a wharf has been built 85 feet long on the river by 133 feet outward, for the purpose of landing coal, sand, etc., for the use of the works. At the northern end of this and at the pier-line a wooden crib is sunk, into the end of which a 24-inch pipe 130 feet long is joined, and conveys the water to the engine-house well. The crib is 3 feet 8 inches by 7 feet 3 inches, divided into two compartments, the outer 2 feet 8 inches by 3 feet 3 inches, and the inner 2 feet 8 inches by 2 feet. The walls and floors have a 4-inch space back of each, filled with concrete. The floor of the inner compartment is 4 feet 8 inches above the level of the outer. In the place of the river-end of the outer compartment a copper-wire screen is fitted in grooves, and another is placed in the division-wall between the compartments, and is 2 feet wide by 3 feet high. To lay the remainder of the pipe, coffer-dams had to be resorted to as far as the engine-house wall. The pipe has a valve-gate operated in the engine-room to shut off the inflow to the well if desirable. The river at the end of the pier is 24 feet deep, and water is drawn at a point 4 feet below low-water level.

The engine-house, located at the head of the pier, is of brick, stone-trimmed, 40 by 50 feet by 30 feet high, with boiler-house from one corner 30 by 40 feet by 20 feet high, and a stack 106 feet high by 11 feet square at base, and an internal section of 3 feet. A two-story house of the same material serves for the engineer's residence, and the effect of the whole station is exceedingly pleasing.

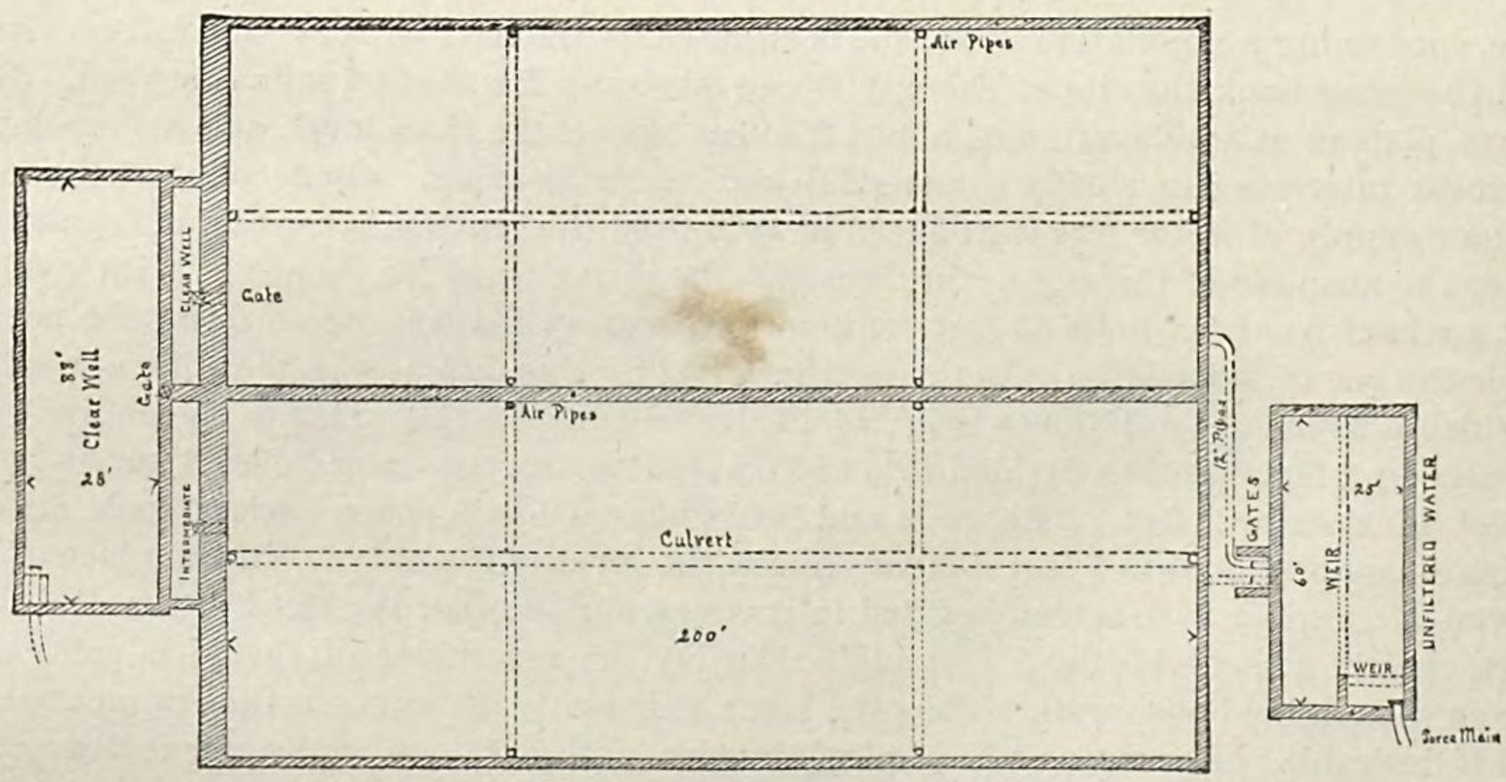
The pump-well, rectangular in plan, is 30 by 10 feet by 20 feet deep below low-water mark (the floor of the engine-house being 8 feet above high, or 12 feet above low water), and divided midway by a weir fitted with an iron gate, now always kept open. One of the compartments was originally intended as the suction-well of the engine pumping into the filter-bed, and the water from the clear well of the latter flowed back into the other compartment

and was drawn up into the suction-pipe of the reservoir pumping-engine—a useless waste of power, considering the high lift into the reservoir. It has now been changed so that the pipe from the clear well is directly connected with the suction-pipe of the engine, thus converting the lift of 9 feet into a head of 17 feet, an effective diminution of the height to be overcome, amounting to 26 feet.

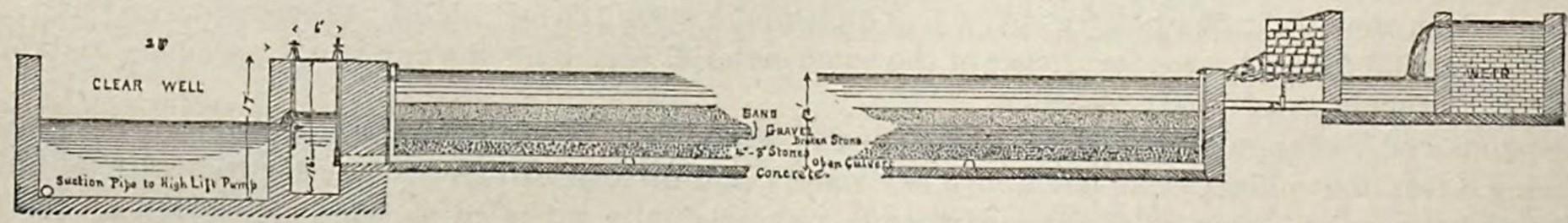
From the pump-well a non-condensing Worthington duplex engine lifts the water 10 feet and forces it through 273 feet of pipe into the unfiltered-water basin, 20 feet above the level of the discharge-valves. This engine has steam-cylinders of 22 inches diameter; pump-plungers, 20 inches in diameter; stroke, 25 inches; daily capacity, 3,000,000 gallons; both pistons, average double strokes per minute, 39. It contains 16 suction- and 16 discharge-valves in each pump-cylinder 7 inches in diameter, consisting of rubber disks 1 inch thick, with iron weights and spiral steel springs around the spindles. Its cost was $5,500, erected in 1872.

The engine for pumping into the reservoir is a Worthington compound duplex, also built in 1872, and of nearly the same size as the above, with low-pressure cylinders of 43 inches diameter; high-pressure cylinders, 24 inches diameter; pump-plungers, 17½ inches diameter; stroke, 30 inches; jet-condenser, 3 feet diameter and 7 feet high; four air-pumps, 14 inches stroke, 3 feet diameter; head on pump, 300 feet of water; daily capacity, 3,000,000 gallons; cost, $28,135, with boilers. The number and arrangement of pump-valves is the same as in the other pumps, and the summary of the engine record for the year 1880 is given below, showing the operation of both:

Hours run:	
Small engine	4,502
Large engine	4,186
Tons (2,240 pounds) coal consumed:	
Small engine	573.08
Large engine	828.40
Banking and starting	124.58
Total	1,526.06
Tons of ash from furnaces	188.18
Percentage of ash	12.24
Gallons of water pumped each month	512,774,130
Tons of coal per 1,000,000 gallons:	
Large engine	1.56
Total	2.84
Average hours run each day:	
Small engine	12.26
Large engine	11.43
Average gallons pumped each day	1,403,292
Average tons of coal each day	4.19



Plan.



Longitudinal section.

FILTER BASIN OF POUGHKEEPSIE WATER-WORKS.

The filtering basin, into which the water is first pumped by the non-condensing engine, is constructed as follows: The water first enters the unfiltered-water basin 25 by 60 feet by 12 feet deep, which is divided into three compartments by walls of masonry. The first and smallest is 11 by 6 feet, whence the water flows over a weir into the second compartment, 11 by 53 feet, and partly settles, thence over a second weir into the third division. From here it passes through 12-inch pipes controlled by gates upon the top of the sand in the basins proper. Of the latter there are two side by side, separated by a 30-inch wall of masonry, and each 200 feet long, 73½ feet wide, and 12 feet deep. On the concrete floor, which is 12 inches thick, is a layer of 24 inches of stones 4 to 8 inches in diameter. Through this layer a main open culvert passes from end to end in the center of the basin with two laterals on each side of it, and is used the more easily to collect the filtered water and convey it into the clear well. At each end of the main and the extremities of the lateral culverts a 6-inch cast-iron pipe passes up above the level of the basin and serves as an exit for air when filling the filter. Above the stones there is another layer of 2-inch broken stone 6 inches deep. Above this is 18 inches of gravel, varying in size from ¼ to 1 inch diameter, and the whole is covered with 24 inches of fine sand. The water above this rises to within about 12 inches of the top of the basin.

The filtered water is led through a gate in an outlet-pipe at the end of each basin into the intermediate clear well, built of masonry, 6 feet wide, 85 feet long, and 16 feet deep. In this the depth of water is kept about 11 inches above the level of the top of the sand in the basin. A square iron gate, 4 by 4½ feet, and operated by a wheel, is located in the middle of the wall separating the intermediate from the clear well. Over the top of this the water flows into the latter. When depressed to its fullest extent the top of this gate is 9 inches below the level of the top of the sand in the basins. The clear-well is 88 feet long, 28 feet wide, and 17 feet deep, the walls being built of masonry, about 18 to 24 inches thick. From one corner of this well the outlet-pipe, 18 inches diameter and 408 feet long, extends to the suction-pipe of the compound or reservoir pumping-engine, giving a head upon the pumps of about 17 feet. The cost of the beds can be seen from the table of cost of construction. They require cleaning once a month, when about half an inch of silt and material is removed from the surface. Once a year the sand is entirely replaced with fresh. The maximum yield of the filtering basins has not yet been accurately ascertained, but it is estimated at about 3,500,000 gallons per day. For its management it requires the services of the mechanical engineer at the pumps and three sand-washers. When cleaned once per month a force of 20 laborers is obtained by advertisement, and they are occupied one day in cleaning it.

The force-main from the pumping-house to the reservoir is 18 inches in diameter and 7,590 feet long. The reservoir inlet is of iron, 3 feet in diameter by 10 feet deep, closing air-tight at top, and entered by the force-main from the west about 4 feet below the ground. The 24-inch supply-pipe line is at the same level.

The reservoir is situated on College hill, to the north of the city, and is irregular in plan to conform to the nature of the locality, about 540 feet long by 210 feet wide and 16 feet depth of water. Height above water-line, 4½ feet, with bottom area of 1.6 acre and at water-line 2.3 acres; its capacity is 12,000,000 gallons. A puddle wall extends through the whole length of the banks, and a thickness of 2 feet from the foot of said wall to the toe of the inner slope. The bottom of the reservoir is not puddled, owing to the fact that it was found to be impervious in itself, but is covered with 3 inches of coarse gravel. The riprap facing extends from 2 to 4 feet below the bottom. The force-main enters the reservoir on the bottom and at the eastern end. The masonry about the pipe rises to a height of 3½ feet above the bottom, and is 2½ by 5 feet in plan. Into this an inlet-main discharges, and immediately around the well the bottom of the reservoir is paved. The inlet-well of cast iron in the eastern bank, and before described, is connected with the masonry well just mentioned by an inlet-main, 24 inches in diameter, passing 4 feet beneath the slope-wall.

About 460 feet to the west of the inlet the effluent gate-house is situated. The supply-pipe leaving it is 24 inches diameter, belled to 26 inches at the outlet-well, where it fits into a cast-iron frame provided with a gate operated from the gate-house above by a screw and wheel. Two screens of copper wire with ⅜-inch mesh are fastened in front of the outlet by grooves in the masonry, and extend above high-water mark. The 24-inch outlet-main branches into mains, one of 12 inches and one of 16 inches diameter, at a point 88 feet from the gate-house, and each is provided with a gate.

A check-valve in the force-main is outside of the engine-house wall, and is accessible through a chamber built for the purpose.

The distribution system comprises about 15.83 miles of cast-iron mains, the great majority of which is of 6 inches diameter. The sizes in use are 24, 18, 16, 12, 8, 6, and 4 inches. Of hydrants there are 292, mostly of Matthews' patent.

Worthington meters are used to a small extent, 130 being the total of all patterns. They are chiefly for attachment to small service-mains.

The number of takers in 1880 was 1,363, and the consumption in 1881 amounted to about 1,500,000 gallons per day.

The first cost of the works is given in an itemized statement below:

Pumping-works:		
Paid for land	$2,000 00	
Paid contractors for wharf, conduit, well, foundations	13,204 76	
Paid for engine-house	14,748 97	
Paid for engineer's house	4,470 78	
Paid for large engine	28,135 80	
Paid for roadway	903 00	
General account, including office, engineering, legal, inspection, superintendence, materials, labor	14,223 46	
		$77,686 77
Filtering-works:		
Paid for land	2,000 00	
Paid contractors	56,701 76	
Paid for small engine	5,500 00	
Paid for well	2,000 00	
Paid for pipe	3,665 01	
Paid for gates	1,084 18	
Paid on general account, including office, engineering, legal, inspection, superintendence, materials, labor	4,743 87	
		75,694 82
Total		153,381 59
Force-main, or pipe from the engine to the reservoir on College hill:		
Paid for right of way	497 00	
Paid contractors for pipe	42,389 42	
Paid contractors for laying pipe	18,381 45	
Paid on general account, including office, engineering, legal, inspection	2,068 33	
		63,336 20
Reservoir:		
Paid for land	7,557 21	
Paid contractors	69,823 58	
Paid for pipe	1,267 24	
Paid for gates	200 00	
Paid for drive	4,391 76	
Paid for walk	475 50	
Paid for grounds	2,074 49	
Paid for fence	562 40	
Paid on general account, including office, engineering, legal, inspection, superintendence, materials, labor	7,850 10	
		94,202 28
Total		310,920 07

At the pumping-station, filter-beds, and reservoir sufficient ground was purchased for additional works when required. The cost of improving these grounds is included in the general accounts.

Distribution:		
Paid contractors for pipe	$55,392 23	
Paid contractors for gates	5,135 50	
Paid contractors for hydrants	6,840 00	
Paid contractors for laying pipe	36,933 69	
Paid on general account, including office, engineering, legal, inspection, superintendence, materials, labor	12,476 96	
		116,778 38
Due contractors on distribution pipe		23,223 93
Due on laying pipe		1,092 00
Total		24,315 93

SUMMARY.

Water-works	$310,920 07
Distribution	116,778 38
Indebtedness January 1, 1873, on construction account	24,315 93
Total	452,014 38

In the next year (1873) 31,600 feet of pipe were laid, and various additions and enlargements have brought the total cost to date (January, 1881) to a grand total of $842,614.

The annual cost of maintenance and repairs for 1880 was $18,626. The character of the water supplied can be seen from the appended analysis by Professor William Ripley Nichols, of the Massachusetts Institute of Technology. Results stated in parts in 100,000:

No. of samples.	Date received.	Locality.	UNFILTERED.		FILTERED.		Inorganic.	Organic volatile.	Total at 212° Fahr.	Total solids after filtration through paper.
			Ammonia.	"Albuminoid ammonia."	Ammonia.	"Albuminoid ammonia."				
408	Nov. 13	River	0.0109	0.0197	0.0109	0.0184	10.4	1.7	12.1	10.1
409	Nov. 13	Clear-water basin	0.0077	0.0139	0.0077	0.0139	8.9	1.1	10.0	9.0
428	Nov. 19	River	0.0104	0.0157	0.0104	0.0157	9.0	1.5	10.5	8.6
427	Nov. 19	Clear-water basin	0.0112	0.0155	0.0112	0.0149	8.1	1.3	9.4	9.0

The specimen numbered 409 was taken just previous to the cleansing of the filter-beds, and was filtered at the rate of 6¾ inches per square foot per hour.

The specimen numbered 427 was a portion of the first water pumped after the cleansing of the beds, and was slightly turbid.

Both specimens of river-water were very turbid.

The works are under the control of a board of commissioners, with Mr. Charles E. Fowler as superintendent.

WATER-WORKS EMPLOYING THE GRAVITY SYSTEM.

CALIFORNIA.

DUTCH FLAT:

Population: 939 inhabitants.
Name of corporation: Dutch Flat Water-Works (private).
Water obtained from: Springs and miners' ditches.
Cost of dam: About $6,000.
Water first introduced: In 1859.
Description of main conduit: Length, 2,000 feet; diameter, 13 inches; material, sheet iron.
Description of distributing reservoir: 60 by 80 feet; 8 feet deep; plank, stone wall banked and roofed.
Sizes of distributing mains: 6-inch cast iron; 2½- to ¾-inch gas-pipe.
Available head: 0 to 200 feet.
Total length of distributing mains: 1½ mile.
Number of water-takers: 50 to 100.
First cost of water-works: About $6,000.
Average annual cost of maintenance and repairs: $200.
Number of fire-plugs: 10.

GRASS VALLEY:

Population: 6,688 inhabitants.
Style of corporation: Municipal.
Water obtained from: South Yuba canal.
Capacity of receiving reservoir: 9,000,000 gallons.
Cost of dam: $75,000.
Water first introduced: In 1858.
Description of main conduit: 6 inches diameter; cast iron.
Description of distributing reservoirs: Three large reservoirs on top of Alta hill.
Sizes of distributing mains: 6 to 4 inches.
Available head: 210 feet (average).
Total length of distributing mains: 6 miles.
Number of water-takers: 550.
First cost of water-works: $30,000.
Average annual cost of maintenance and repairs: $800.

LOS ANGELES:

Population: 11,183 inhabitants.
Name of corporation: Los Angeles City Water Company (private).
Water obtained from: Los Angeles river.
Total area of water-shed available: 182 square miles.
Character and dimensions of dams: No. 1—150 feet long; 8 feet wide on top; 40 feet deep; slope 1½ to 1; earth. No. 2—200 feet long; 6 feet wide on top; 22 feet deep; slope 1½ to 1; puddle wall in center, 6 feet wide; puddle 16 inches on face; clay and sand.
Cost of dams: No. 1—$5,000, in a cañon; No. 2—$2,650.
Water first introduced: In 1868.
Description of main conduit: Open ditch; length, 35,000 feet; cross-section, 4 feet (average); sides slope 1 to 1; average depth, 1 foot.
Discharging capacity: 4 cubic feet per second.
Description of distributing reservoirs: Capacity of No. 1, 5,600,000 gallons; of No. 2, 800,000 gallons; No. 1, drawn 16 feet below surface, pipe passes under embankment laid in a trench; No. 2, drawn 15 feet deep.
Sizes of distributing mains: 22 inches and 13 inches to 1 inch.

LOS ANGELES—Continued.

Available head: 20 to 120 feet; water-supply sometimes deficient in summer.
Total length of distributing mains: 23 miles.
Number of water-takers: About 1,500.
Consumption of water: 125 gallons per head daily (estimated).
First cost of water-works: $375,000.
Average annual cost of maintenance and repairs: $6,000.
Number of fire-plugs: 60.

MISSION SAN JOSÉ:

Population: 246 inhabitants.
Name of corporation: Mission Water-Works (private).
Water obtained from: Spring.
Cost of dam: $1,500.
Water first introduced: In 1871.
Description of distributing reservoir: Circular; 30 feet diameter, 11 feet deep; concrete.
Size of distributing mains: 3 inches.
Available head: 50 feet (average).
Total length of distributing mains: 2,200 feet.
Number of water-takers: 30.
Consumption of water: 6,000 gallons per day (estimated).
First cost of water-works: About $5,000.

OAKLAND:

Population: 34,555 inhabitants.
Name of corporation: Contra Costa Water Company (private).
Water obtained from: Artificial lake.
Total area of water-shed available: 50 square miles.
Capacity of lake: 20,000,000,000 gallons.
Character and dimensions of dam: 300 feet long; 75 feet high; built on solid bed-rock; packed in layers 12 inches thick; slope 1 to 3; can be made 100 feet higher if necessary; no leakage.
Cost of dam: $3,000,000.
Water first introduced: In 1876.
Description of main conduit: Length, 8 miles; diameter, 24 inches; plate iron, riveted and caulked, tar-coated.
Discharging capacity: 5,000,000 to 7,000,000 gallons per 24 hours, under 216 feet head (average).
Sizes of distributing mains: From 24 to 3 inches.
Available head: 40 to 75 pounds; water-supply deficient at lowest head.
Total length of distributing mains: About 100 miles.
Consumption of water: 300 gallons per head per day (estimated).
First cost of water-works: $3,000,000.
Average annual cost of maintenance and repairs: About $60,000.
Description of filtering apparatus: Through cotton cloths set in frames in summer; cleaned every 24 hours.
Number of fire-plugs: 200, made in Oakland.

PETALUMA:

Population: 3,326 inhabitants.
Name of corporation: The Sonoma County Water Company (private).
Water obtained from: Adobe creek.
Total area of water-shed available: 36 square miles.

PETALUMA—Continued.

Water first introduced: In 1872.

Description of main conduit: Length, 5½ miles; diameter, 7 inches; wrought iron, riveted.

Discharging capacity: 300,000 gallons per day; head, 50 feet (average).

Description of distributing reservoir: Excavation in hard pan, 100 by 100 feet; capacity, 500,000 gallons.

Sizes of distributing mains: 7, 6, 5, 2½, and 1½ inches.

Available head: 50 to 170 feet.

Total length of distributing mains: About 12 miles.

Number of water-takers: 620.

Consumption of water: 75 gallons per head per day (estimated).

First cost of water-works: $100,466 37.

Average annual cost of maintenance and repairs: $1,000.

Number of fire-plugs: 15, various designs.

PLACERVILLE:

Population: 1,951 inhabitants.

Name of corporation: Placerville Water Company (private).

Water obtained from: American river (South fork).

Total area of water-shed available: About 250 square miles.

Water first introduced: In 1852.

Description of main conduit: Wood, 3,360 feet long, 6 by 6 inches; and plate iron, 1,000 feet long, diameter, 7 inches.

Description of distributing reservoir: Simply earth embankment; receiving reservoir capacity, 2,500,000 gallons.

Sizes of distributing mains: 7, 3, 2½, and 2 inches.

Available head: 125 feet (average); water-supply sometimes deficient.

Total length of distributing mains: 8,700 feet.

Number of water-takers: 100.

Consumption of water: 175 gallons per head per day.

First cost of water-works: $30,000.

Number of fire-plugs: 4.

SAN JOSÉ:

Population: 12,567 inhabitants.

Name of corporation: San José Water Company (private).

Water obtained from: River and reservoir.

Total area of water-shed available: 50 square miles.

Capacity of receiving reservoir: 500,000,000 gallons.

Material of dam: Earth.

Cost of dam: $80,000.

Water first introduced: In 1870.

Description of main conduit: Flume, 24 by 24 inches, wood; pipe, 18 inches, No. 14 iron.

Discharging capacity: 5,000,000 gallons per day, 40 pounds head (average).

Description of distributing reservoir: Capacity, 5,000,000 gallons; dam of earth.

Size of distributing mains: 11 inches.

Available head: 40 pounds (average).

Total length of distributing mains: 56 miles.

Number of water-takers: 2,000.

Consumption of water: 3,000,000 gallons daily in summer and 1,000,000 gallons daily in winter (estimated).

First cost of water-works: $413,500.

Average annual cost of maintenance and repairs: About $20,000.

SAN RAFAEL:

Population: 2,276 inhabitants.

Name of corporation: Marin County Water Company (private).

Water obtained from: Springs and surface-water.

Capacity of receiving reservoir: 175,000,000 gallons.

Character and dimensions of dam: 400 feet long, earth and clay.

Cost of dam: About $400,000 by old company; present company bought property.

Water first introduced: In 1872.

Description of main conduit: Diameter, 8 inches; No. 14 iron, riveted joints.

SAN RAFAEL—Continued.

Description of distributing reservoirs: Capacity of No. 1, 1,000,000 gallons; of No. 2, 250,000 gallons; brick, cement-lined.

Sizes of distributing mains: 8 to 6 inches.

Available head: 90 pounds pressure (average).

Total length of distributing mains: 23 miles.

Number of water-takers: 400.

Consumption of water: 200 gallons per head per day (estimated very closely).

First cost of water-works: $350,000 to present company.

Average annual cost of maintenance and repairs: $14,000.

Number of fire-plugs: 25.

SANTA BARBARA:

Population: 3,460 inhabitants.

Name of corporation: Mission Water Company (private).

Water obtained from: Mountain streams.

Capacity of receiving reservoir: 100,000 gallons.

Character and dimensions of dam: Length, 125 feet; width at top, 14 feet; at base, 20 feet; stone and brick; built by Indians.

Cost of dam: $30,000.

Water first introduced: In 1872.

Description of main conduit: Sheet-iron pipes—length, 1,000 feet, diameter, 6 inches; and wrought-iron pipes—length 5,000 feet, diameter, 5 inches by 4 inches.

Description of distributing reservoir: 105 by 104 feet, 7 to 10 feet deep; sloping to discharge-pipe; stone side-walls, with concrete bottom.

Sizes of distributing mains: 6, 5, 4, 3, and 2 inches.

Available head: 75 pounds to square inch (average).

Total length of distributing mains: 5 miles.

Number of water-takers: 225.

Consumption of water: 15,000 gallons daily.

First cost of water-works: 25,000.

Average annual cost of maintenance and repairs: $600.

Description of filtering apparatus: Redwood and brass-wire screens, 6 by 10, 6 feet high; cleaned in summer every 15 days, in winter every 30 days.

Number of fire-plugs: 13; globe-valves and nipples.

SANTA CLARA:

Population: 2,416 inhabitants.

Name of corporation: San José Water Company (private).

Water first introduced: In 1870.

Description of main conduit: Length, 2 miles; diameter, 7 inches; sheet iron.

Number of water-takers: 250.

Number of fire-plugs: 25.

TRUCKEE:

Population: 1,147 inhabitants.

Style of corporation: Private.

Water obtained from: Springs.

Dimensions of receiving reservoir: 28 by 60 feet; 6 feet deep.

Cost of dams: $9,000.

Water first introduced: In 1868.

Description of main conduit: Length, 2,000 feet; diameter, 11 inches; iron.

Description of distributing reservoir: Length, 60 feet; width, 28 feet; depth, 6 feet; wood.

Sizes of distributing mains: 8, 4, and 3 inches.

Available head: 100 feet (average).

Total length of distributing mains: 3,000 feet.

Number of water-takers: 80.

Average annual cost of maintenance and repairs: About $200.

Number of fire-plugs: 10.

WASHINGTON:

Population: 195 inhabitants.

Style of corporation: Municipal.

Water obtained from: Spring.

Water first introduced: In 1856.

WASHINGTON—Continued.

Description of main conduit: Length, 600 feet; diameter, 1½ inch; galvanized iron.

Discharging capacity: 5 gallons per minute; head, 15 feet (average).

Consumption of water: 200 gallons per head per day (estimated.)

First cost of water-works: $300.

Average annual cost of maintenance and repairs: $25.

WATSONVILLE:

Population: 1,799 inhabitants.

Names of corporations: Watsonville Water Company and Corralitos Water Company.

Water obtained from: Corralitos creek.

Cost of dam: $1,500.

Water first introduced: July, 1868.

Description of main conduit: Boiler iron—length, 1½ mile; diameter, 8 inches. Wooden flume—length, 7 miles.

Description of distributing reservoir: Excavation and embankment; capacity, 3,000,000 gallons.

Sizes of distributing mains: 8, 4, and 3 inches.

Available head: 93 feet (average).

Total length of distributing mains: About 9 miles.

Number of water-takers: 200.

Consumption of water: 200,000 gallons per day (estimated).

First cost of water-works: About $40,000.

Average annual cost of maintenance and repairs: $1,200.

Number of fire-plugs: 18.

YREKA:

Population: 1,059 inhabitants.

Name of corporation: Yreka Water-Works (private).

Water obtained from: Culverts in bottom of mining gulches.

Total area of water-shed available: About 8 square miles.

Capacity of receiving reservoir: 60,000 gallons.

Cost of dam: $10,000 or $11,000.

Water first introduced: June, 1862.

Description of main conduit: Bored logs—length, ½ mile, diameter, 4½ inches; iron—length, ½ mile, diameter, 3 inches.

Discharging capacity: 75,000 gallons per 24 hours (average).

Size of distributing mains: 2 inches.

Available head: 50 feet (average); water-supply very seldom deficient.

Total length of distributing mains: About 1 mile.

Number of water-takers: 90.

Consumption of water: 75,000 gallons per day (estimated).

First cost of water-works: $15,000.

Filtering apparatus: Cleaned once a year.

COLORADO.

CARIBOU:

Population: 549 inhabitants.

Style of corporation: Municipal.

Water obtained from: Ditch 1½ mile long, fed by melting snow in summer and by springs in winter.

Cost of dam: $2,000.

Water first introduced: October, 1878.

Description of main conduit: Length, 400 feet; diameter, 4 inches; iron.

Description of distributing reservoir: 20 by 20 feet by 12 feet deep; supplied from ditch.

Sizes of distributing mains: 4 and 2 inches.

Total length of distributing mains: 1,400 feet.

Number of water-takers: About 15.

First cost of water-works: $2,000.

Average annual cost of maintenance and repairs: $300.

Number of fire-plugs: 5.

COLORADO SPRINGS:

Population: 4,226 inhabitants.

Style of corporation: Municipal.

Water obtained from: Mountain streams.

Area of receiving reservoir: ½ acre.

Cost of dam: $7,000.

COLORADO SPRINGS—Continued.

Water first introduced: December, 1878.

Description of main conduit: Length, 6 miles; diameter, 12, 10, and 8 inches.

Description of distributing reservoir: Built in a basin; capacity about 1,000,000 gallons; inflow, 500,000 gallons per day.

Sizes of distributing mains: 6, 4, 3, and 2 inches.

Available head: 120 pounds (average).

Total length of distributing mains: About 9 miles.

Consumption of water: 100 gallons per head (estimated).

First cost of water-works: $80,000.

Average annual cost of maintenance and repairs: $2,000.

Number of fire-plugs: 30; Holly patent.

CONNECTICUT.

ANSONIA:

Population: 3,855 inhabitants.

Names of corporations: Fountain Water Company and Ansonia Water Company (private).

Water obtained from: Brooks and springs.

Total area of water-shed available: About 50 acres.

Capacity of receiving reservoir: About 630,000 cubic feet.

Character and dimensions of dam: Built of stone; 175 feet long, 18 feet high; curves 10 feet toward water; 8 feet thick at bottom, 3 feet 6 inches thick on top; lapped with stone 9 inches thick across dam; inside filled with earth, leaning at an angle of 45 degrees.

Cost of dam: About $3,500.

Water first introduced: December, 1872.

Description of main conduit: Length, 4 miles; diameter, 8, 6, 4, and 3 inches; sheet iron, cement-lined.

Description of distributing reservoir: Main pipe enters penstock in center of reservoir, near bottom; the penstock is 20 feet high, 32 inches in diameter, and constructed with sliding gates.

Sizes of distributing mains: 6, 4, and 3 inches.

Available head: 90 feet (average).

Number of water-takers: 220.

First cost of water-works; $16,000.

Number of fire-plugs: 23; Holyoke patent.

BETHEL:

Population: 1,767 inhabitants.

Style of corporation: Municipal.

Water obtained from: Springs and surface-water.

Total area of water-shed available: About 150 to 200 acres.

Area and capacity of receiving reservoir: 35 acres; 84,000,000 gallons (estimated).

Character and dimensions of dam: 200 feet long, 80 feet wide, 20 feet high, 12 feet top; earthwork; center wall of stone, 3 feet thick; flume in center, of stone, 20 feet long, 4 feet wide, for gates and filters.

Cost of gate-house: $125.

Water first introduced: September, 1878.

Description of distributing reservoir: A natural basin, between hills, containing 35 acres.

Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.

Available head: 60 to 80 pounds per square inch.

Total length of distributing mains: 25,816 feet.

Number of water-takers: 145.

First cost of water-works: $26,100 21.

Average annual cost of maintenance and repairs: Not over $100.

Description of filtering apparatus: First compartment, 4 by 6 feet by 14 feet deep; second compartment, 2 by 4 feet; third compartment, full of clear water; material, charcoal and sponges.

Number of fire-plugs: 26; Matthews patent.

BIRMINGHAM:

Population: 3,026 inhabitants.

Name of corporation: Birmingham Water Company (private).

Water obtained from: Springs and brook.

Area of receiving reservoirs: 8,160,000 feet in two reservoirs.

BIRMINGHAM—Continued.

Character and dimensions of dams: No. 1, stone, overflow 20 feet wide, 12 feet high; wing-wall run back 4 feet; earth filling 500 feet long; 10 feet high on each side of overflows; No. 2, stone, overflow 15 feet wide, 10 feet high; wing-wall and earth filling 12 feet high, 200 feet long.
Cost of dams: No. 1, $11,700; No. 2, $13,300.
Water first introduced: In 1860.
Description of main conduit: Length, 2,054 feet; diameter, 12 and 8 inches; cast iron.
Sizes of distributing mains: 12, 8, 6, and 4 inches.
Available head: 120 feet (average).
Total length of distributing mains: About 5 miles.
Number of water-takers: 250.
Consumption of water: 2,500 gallons (estimated).
First cost of water-works: $28,000.
Average annual cost of maintenance and repairs: $250.
Number of fire-plugs: 47.

DANBURY:

Population: 11,666 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs and small brooks.
Total area of water-shed available: About 1,000 acres.
Capacity of receiving reservoirs: 300,000,000 gallons; 2 reservoirs.
Character and dimensions of dams: Length of each, 300 to 400 feet; height, 25 to 30 feet; slope, 2 to 1 inside, 1½ to 1 outside; built 5 feet above water-level; earth; puddle walls in center.
Cost of dams: About $30,000.
Water first introduced: December, 1860.
Description of main conduit: Length, 1¼ mile; diameter, 10 inches; sheet iron, lined and covered with cement.
Sizes of distributing mains: 8, 6, 4, 3, and 1 inches.
Available head: 40 to 190 feet; water-supply sometimes deficient.
Total length of distributing mains: About 15 miles.
Number of water-takers: About 1,000.
First cost of water-works: $37,500.
Average annual cost of maintenance and repairs: $800 to $1,000.

GREENWICH:

Population: 7,892 inhabitants.
Name of corporation: Greenwich Water Company (private).
Water obtained from: Artificial lake, fed by springs and river.
Total area of water-shed available: About 1 square mile.
Capacity of receiving reservoir: 234,297,536 gallons.
Character and dimensions of dam: 485 feet long, 20 feet wide; puddle earth; stone wall in cement through length from top to bottom; escape, 54 feet wide; stone and cement with filtering chamber.
Cost of dam: About $35,000.
Water first introduced: September, 1880.
Description of main conduit: Length, 1 mile, diameter 16 inches; and 3 miles, diameter 12 inches; cast iron.
Sizes of distributing mains: 10, 8, 6, and 4 inches.
Available head: 50 to 125 pounds.
Total length of distributing mains: About 2⅛ miles.
Number of water-takers: 15.
First cost of water-works: $70,000.
Description of filtering apparatus: 6 feet wide through dam; 3 chambers—1st, charcoal; 2d, sponges; water enters main from 3d; sponges cleaned four times a year.
Number of fire-plugs: 24.

MERIDEN:

Population: 15,546 inhabitants.
Name of corporation: Meriden Water-Works (municipal).
Water obtained from: Water-shed.
Total area of water-shed available: 800 acres.
Area and capacity of receiving reservoir: Length, 1 mile, width, ⅛ mile; capacity, 300,000,000 gallons.
Character and dimensions of dam: Earthwork.

MERIDEN—Continued.

Cost of dam: $350,000.
Water first introduced: In 1869.
Description of main conduit: Length 3 miles, diameter 12 inches, cast iron, cement-lined; and length 2½ miles, diameter 16 inches, cast iron.
Sizes of distributing mains: From 8 to 1 inches.
Available head: Water-supply failed on one occasion.
Total length of distributing mains: 22 miles.
Number of water-takers: 1,500.
Consumption of water: 90 gallons per head daily (estimated).
First cost of water-works: $275,000.
Average annual cost of maintenance and repairs: About $6,000.
Number of fire-plugs: 190.

NEW BRITAIN:

Population: 11,800 inhabitants.
Name of corporation: City of New Britain Water-Works (municipal).
Water obtained from: Shuttle Meadow lake.
Total area of water-shed available: About 2 square miles.
Area and capacity of receiving reservoir: 175 acres; 650,000,000 gallons.
Character and dimensions of dam: 600 feet long, 20 feet high, 30 feet wide on top; bank, with waste-weir in center of substantial masonry, 30 feet wide.
Cost of dam: Original cost, $50,000; present cost, $171,000.
Water first introduced: October, 1857.
Description of main conduit: Length, 2¼ miles; diameters, 16 and 12 inches; wrought iron and cement.
Description of distributing reservoir: ¼ mile from city; 146 feet above level of business part; used as a reserve and protection if mains should fail.
Sizes of distributing mains: From 8 to 2 inches.
Available head: 70 to 80 pounds.
Total length of distributing mains: About 30 miles.
Number of water-takers: 1,350.
First cost of water-works: $50,000.
Average annual cost of maintenance and repairs: $2,800.
Number of fire-plugs: 152.

NEW MILFORD:

Population: 1,416 inhabitants.
Name of corporation: New Milford Water Company (private).
Water obtained from: Springs and running streams.
Total area of water-shed available: About 1,000 acres.
Capacity of receiving reservoir: About 2,000,000 gallons.
Character and dimensions of dam: 148 feet long, 16 feet 6 inches base, 4 feet 10 inches top, 22 feet high; overflow 20 feet long, 2 feet deep, flooding ¾ acre; stone masonry.
Cost of dam: $9,203 08.
Water first introduced: In 1874.
Description of main conduit: 1—length 60 feet, diameter 10 inches. 2—length 9,108 feet, diameter 6 inches. 3—length 12,774 feet, diameter 4 inches; iron.
Sizes of distributing mains: 6 and 4 inches.
Number of water-takers: 134.
First cost of water-works: $29,891 99.
Average annual cost of maintenance and repairs: $541 40.
Description of filtering apparatus: Size, 12 by 12 feet; brick; charcoal and gravel; cleaned once a year.
Number of fire-plugs: 32.

ROCKVILLE:

Population: 5,902 inhabitants.
Name of corporation: Rockville Aqueduct Company (private).
Water obtained from: Shenipsit lake.
Area of receiving reservoir: 524 acres.
Character and dimension of dam: Length 50 feet, width 18 feet; granite, laid in water cement.
Water first introduced: In 1846.
Sizes of distributing mains: 15 to 2 inches.
Available head: 75 to 279 feet.
Total length of distributing mains: About 8 miles.
Number of water-takers: 350 to 375.

ROCKVILLE—Continued.
First cost of water-works: $22,000.
Average annual cost of maintenance and repairs: $1,000.
Number of fire-plugs: 50.

SHELTON:
Population: 1,362 inhabitants.
Name of corporation: The Shelton Water-Works (private).
Water obtained from: Brook.
Capacity of receiving reservoir: 2,750,000 gallons.
Character and dimensions of dam: Length 110 feet, height 25 feet; side-wall, on one side 60 feet long, 18 feet thick on bottom, 4 feet on top; overflow, 40 feet wide; walls on sides rise 4 feet above overflow; stone; stone-work grouted.
Cost of dam: $5,435 20.
Water first introduced: October, 1879.
Description of main conduit: Length 2,494 feet, diameter 12 inches; cast iron.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 200 feet (average).
Total length of distributing mains: 2.345 miles.
Number of water-takers: 45.
Consumption of water: 30,000 gallons daily (estimated).
First cost of water-works: $16,306 37.
Average annual cost of maintenance and repairs: Less than $100.
Number of fire-plugs: 15.

SIMSBURY:
Population: 1,830 inhabitants.
Name of corporation: Simsbury Water Company (private).
Water obtained from: Small streams.
Area of receiving reservoir: 1 acre.
Character and dimensions of dam: 5 feet high, 8 feet wide; wings into high ground on either side.
Description of main conduit: Length 1½ mile, diameter 6 inches; iron.
Available head: 75 feet (average).
Total length of distributing mains: About ½ mile.
Number of water-takers: 19.
First cost of water-works: $13,000.
Average annual cost of maintenance and repairs: $25.
Number of fire-plugs: 10.

SOUTH NORWALK:
Population: 3,726 inhabitants.
Style of corporation: Municipal.
Water obtained from: Streams.
Total area of water-shed available: 9 square miles.
Area of receiving reservoirs: 1st, 17 acres; 2d, 4 acres.
Character and dimensions of dams: No. 1—207 feet long, 31 feet high; No. 2—205 feet long, 15 feet high; gravel and clay, with core of cemented masonry; width on top, 20 feet; lower slope, 1½ to 1; pond slope, 2 to 1.
Cost of dams: No. 1, $6,086; No. 2, $7,536.
Water first introduced: December, 1875.
Description of main conduit: Length 4⅝ miles, diameter 12 inches; cast iron.
Description of distributing reservoir: Natural basin, with dam 13 feet high.
Sizes of distributing mains: 12 to 4 inches.
Available head: 80 pounds per square inch (average).
Total length of distributing mains: 7 miles.
Number of water-takers: About 300.
Consumption of water: 250,000 gallons per day (estimated).
First cost of water-works: $100,724 62.
Average annual cost of maintenance and repairs: About $500.
Description of filtering system: Charcoal, 4 by 4 by 8 feet; sponge, 4 by 4 by 8 feet; cleaned twice a year.
Number of fire-plugs: 53.

STAMFORD:
Population: 11,297 inhabitants.
Name of corporation: Stamford Water Company (private).
Water obtained from: Mill river and Trinity lake.
Water first introduced: July, 1871.

STAMFORD—Continued.
Sizes of distributing mains: 10, 8, 6, and 4 inches.
Total length of distributing mains: About 10 miles.
Number of water-takers: 536.
Consumption of water: 300,000 gallons daily (estimated).
Number of fire-plugs: 53.

WATERBURY:
Population: 17,806 inhabitants.
Name of corporation: Waterbury City Water-Works (municipal).
Water obtained from: Springs.
Total area of water-shed available: 1 square mile.
Capacity of receiving reservoirs: 1st, 100,000,000 gallons; 2d, 8,000,000 gallons; 3d, 10,000,000 gallons.
Character and dimensions of dam: 18 to 30 feet high, 200 to 800 feet long; earth, with puddle center; pond-slope faced with stone paving; lower slope, sod.
Cost of dam: $50,000.
Water first introduced: January, 1868.
Description of main conduit: Length 12,700 feet, diameter 12 inches; wrought iron, lined, and covered with cement.
Discharging capacity: Over 3,000,000 gallons per day; head, 230 feet (average).
Description of distributing reservoir: 3 acres; 8,000,000 gallons.
Sizes of distributing mains: 12 to 1 inches.
Available head: 100 pounds (average); head impaired on high ground.
Total length of distributing mains: About 29 miles.
Number of water-takers: 63.
Consumption of water: 1,000,000 gallons per day (estimated).
First cost of water-works: $325,000.
Average annual cost of maintenance and repairs: $3,000.

WEST WINSTED:
Population: 3,000 inhabitants.
Name of corporation: Winsted Water-Works (municipal).
Water obtained from: Lake.
Water first introduced: In 1862.
Description of main conduit: Length 3 miles, diameters 12, 8, and 6 inches; cast iron, cement-lined.
Discharging capacity: 180 gallons per hour.
Sizes of distributing mains: 12, 8, and 4 inches.
Available head: 160 feet (average).
Number of water-takers: About 500.
First cost of water-works: $25,000.

WINDSOR:
Population: 3,058 inhabitants.
Name of corporation: Windsor Water-Works (private).
Water obtained from: Springs and surface-water.
Total area of water-shed available: About 50 acres.
Dimensions of receiving reservoir: 300 by 500 feet; 10 feet deep.
Character and dimensions of dam: Earth embankment, with canal on one side lined with stone, about 2 feet on top; has gates for outlet.
Cost of dam: $6,000.
Water first introduced: In 1877.
Description of main conduit: Part length, 600 feet, diameter 8 inches, iron; part length, 1 mile, diameter 6 inches, iron.
Size of distributing mains: 6 inches.
Available head: 60 feet (average).
Total length of distributing mains: 2 miles.
Number of water-takers: 30.
First cost of water-works: $6,000.
Average annual cost of maintenance and repairs: Not over $25.
Description of filtering apparatus: Only brick, with plaster joints at well-house.
Number of fire-plugs: 8.

WOLCOTTVILLE:
Population: 2,245 inhabitants.
Name of corporation: Wolcottville Water Company (private).
Water obtained from: Running stream.
Total area of water-shed available: 6 square miles.

WOLCOTTVILLE—Continued.

Area and capacity of receiving reservoir: 5½ acres; 16,000,000 gallons.
Character and dimensions of dam: 234 feet long, 20 feet high; wall of grouted masonry, 8 feet thick at base and 2 feet 6 inches on top; earth embankment; slope, 1½ to 1.
Cost of dam: $5,944 52.
Water first introduced: August, 1878.
Description of main conduit: Length 11,468 feet, diameter 10 inches; iron.
Sizes of distributing mains: 6 and 4 inches.
Available head: 170 feet (average).
Total length of distributing mains: 18,187 feet.
Number of water-takers: 197.
First cost of water-works: $30,000.
Average annual cost of maintenance and repairs: About $500.
Description of filtering apparatus: Two chambers, one charcoal and the other sponges; cleaned twice a year.
Number of fire-plugs: 37.

DAKOTA.

DEADWOOD:

Population: 3,777 inhabitants.
Name of corporation: Deadwood Water Company (private).
Water obtained from: City and Whitewood creeks.
Total area of water-shed available: 14 square miles.
Capacity of receiving reservoir: 300,000 gallons.
Cost of dam: $15,000.
Water first introduced: September, 1879.
Sizes of distributing mains: 6, 4, and 3 inches.
Available head: 95 pounds (average).
Total length of distributing mains: About 3 miles.
Number of water-takers: 250.
Consumption of water: 125,000 gallons per day (estimated).
First cost of water-works: $40,000.
Average annual cost of maintenance and repairs: $5,000.
Number of fire-plugs: 15.

GEORGIA.

MACON:

Population: 12,749 inhabitants.
Name of corporation: Macon Gas-Light and Water Company.
Water obtained from: Springs.
Capacity of receiving reservoir: 140,000 gallons.
Water first introduced: In 1867.
Description of main conduit: Length 3,000 feet, diameter 4 inches; cast iron.
Discharging capacity: 26,928 gallons per minute; head, 73 feet (average).
Description of distributing reservoir: 4 circular cisterns; capacity, 150,000 gallons.
Sizes of distributing mains: 4, 3, and 2 inches.
Available head: 70 feet (average); water-supply deficient in summer.
Total length of distributing mains: 7,424 feet.
Number of water-takers: 84.
Consumption of water: In winter, 30,000 gallons per day; in summer 19,000 gallons per day.
First cost of water-works: $14,000.

MAINE.

AUBURN:

Population: 9,555 inhabitants.
Name of corporation: Auburn Aqueduct Company (private).
Water obtained from: Wilson pond.
Total area of water-shed available: 10,000 acres.
Water first introduced: In 1869.
Description of main conduit: First part, length 3,000 feet, diameter 12 inches; second part, length 2½ miles, diameter 10 inches; cast-iron.
Discharging capacity: 1,500,000 gallons in 24 hours; head, 118 feet (average).

AUBURN—Continued.

Description of distributing reservoir: Main distribution direct from pond; iron reservoir; capacity, 500,000 gallons.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 70 to 118 feet.
Total length of distributing mains: 10 miles.
Number of water-takers: 800.
Consumption of water: 45 gallons per head daily (estimated).
First cost of water-works: $125,000.
Average annual cost of maintenance and repairs: $2,000.
Number of fire-plugs: 24.

SKOWHEGAN:

Population: 2,609 inhabitants.
Style of corporation: Three principal companies—private.
Water obtained from: Springs.
Description of main conduit: Length 2 miles, diameters 4 and 3 inches.
Discharging capacity: 200,000 gallons per day; head, 10 to 25 feet.
Sizes of distributing mains: 4, 3, 2, 1, ¾, and ½ inches.
Available head: 10 to 25 feet.
Total length of distributing mains: Between 2 and 3 miles.
Number of water-takers: Between 300 and 400.
First cost of water-works: $15,000.
Average annual cost of maintenance and repair: Between $300 and $400.

SPRINGVALE:

Population: 1,116 inhabitants.
Name of corporation: Springvale Aqueduct Company (private).
Water obtained from: Pond.
Area of receiving reservoir: 40 acres.
Water first introduced: In 1876.
Description of main conduit: Diameter, 4½ inches; iron.
First cost of water-works: $7,000.
Average annual cost of maintenance and repairs: About 2 per cent. on first cost.
Number of fire-plugs: 1 hydrant and many plugs.

MARYLAND.

FROSTBURG:

Population: 4,057 inhabitants.
Name of corporation: Frostburg Water-Works (private).
Water obtained from: Springs.
Total area of water-shed available: About 2 square miles.
Character and dimensions of dam: 100 feet long; built of wood.
Cost of dam: $4,590.
Water first introduced: In 1854.
Description of main conduit: Part length 100 feet, shape, square, 2 by 2 feet, wood; part length 1 mile, diameter 6 inches, cast iron.
Discharging capacity: 10 to 400 gallons per minute; head, 70 feet (average).
Description of distributing reservoir: Area, 50 feet square, 15 feet deep; stone laid in cement.
Sizes of distributing mains: 8 to 6 inches.
Available head: 10 to 100 feet; water-supply deficient in dry weather.
Total length of distributing mains: About 11,000 feet.
Number of water-takers: About 160.
Consumption of water: 10 gallons per head per day (estimated).
First cost of water-works: $10,000.
Average annual cost of maintenance and repairs: About $300.
Number of fire-plugs: 15.

MASSACHUSETTS.

AGAWAM:

Population: 2,216 inhabitants.
Name of corporation: Agawam Water-Works (private).
Water obtained from: Springs.
Character of dam: All puddle-clay.

AGAWAM—Continued.

Water first introduced: January, 1877.
Description of main conduit: Diameter, 6 inches; wrought iron; cement-lined.
Available head: 30 to 40 feet.
Total length of distributing mains: 2 miles.
Number of water-takers: 33.
First cost of water-works: $6,000.

ARLINGTON:

Population: 4,100 inhabitants.
Style of corporation: Municipal.
Water obtained from: Great meadows and water-shed.
Area of receiving reservoir: 27 acres.
Character and dimensions of dam: 850 feet long, 13 feet high; blue gravel and earth; built across valley to form storage reservoir.
Water first introduced: In 1873.
Description of main conduit: Diameters, 12, 6, and 4 inches; sheet iron, covered and lined with cement.
Discharging capacity: 2,000,000 gallons in 24 hours; head, 117 feet (average).
Description of distributing reservoir: Formed by building a dam across valley; capacity, 73,500,000 gallons.
Sizes of distributing mains: 12, 6, and 4 inches.
Available head: 117 feet (average).
Total length of distributing mains: 73,342 feet.
Number of water-takers: 438.
First cost of water-works: $300,000.
Average annual cost of maintenance and repairs: About $1,500.
Description of filtering apparatus: Excavation in natural bank of coarse gravel at side of reservoir, 230 feet long, 12 feet wide, 12 feet deep; covered with semicircular arch of brick, 8 inches thick, sprung from stone; side walls 4 feet high; no cleaning.
Number of fire-plugs: 98.

ATHOL:

Population: 4,307 inhabitants.
Name of corporation: Athol Water Company (private).
Water obtained from: Mountain streams.
Total area of water-shed available: About 4 square miles.
Area and capacity of receiving reservoir: 27 acres; 15 feet deep.
Character and dimensions of dam: 450 feet long, 18 feet high; puddle sand, with stone center.
Cost of dam: About $16,000.
Water first introduced: In 1876.
Description of main conduit: Length 10 miles, diameter 10 inches; cast iron.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 300 feet (average).
Total length of distributing mains: About 8 miles.
Number of water-takers: 250.
First cost of water-works: $80,000.
Average annual cost of maintenance and repairs: $500.
Filtering apparatus: Size, 4 feet square; sand.
Number of fire-plugs: 50.

CHICOPEE:

Population: 11,286 inhabitants.
Name of corporation: Chicopee Water Company (private).
Water obtained from: Brooks and springs.
Character and dimensions of dam: 250 feet long, 14 feet high, 12 feet wide on top; each embankment 6-inch piles in center; batter, 1½ to 1.
Cost of dam: About $5,000.
Water first introduced: In 1877.
Description of main conduit: Length 5,000 feet, diameter 8 inches; iron, cement-lined.
Sizes of distributing mains: 4, 3, and 2 inches.
Available head: About 72 feet (average).
Total length of distributing mains: About 6 miles.
First cost of water-works: $55,000.
Average annual cost of maintenance and repairs: $400.

FITCHBURG:

Population: 12,429 inhabitants.

FITCHBURG—Continued.

Name of corporation: Fitchburg Water-Works (municipal).
Water obtained from: Water-shed.
Total area of water-shed available: 1,800 acres.
Area and capacity of receiving reservoirs: 1st, 13 acres; 60,000,000 gallons; 2d, 35 acres; 200,000,000 gallons.
Character and dimensions of dams: 1st, 43 feet high; 151 feet base; 22 feet wide on top; earth, with spiling wall; 2d, 46 feet high; 245 feet base; 35 feet wide on top; gravel and hard pan.
Cost of dams: No. 1, $38,239; No. 2, $32,500.
Water first introduced: In 1872.
Description of main conduit: Length 1½ mile, diameter 2 feet; brick.
Sizes of distributing mains: 16, 14, 12, 10, 8, 6, 4, and 2 inches.
Available head: 264 to 373 feet.
Total length of distributing mains: About 24 miles.
Number of water-takers: 1,913.
Consumption of water: 1,250,000 gallons per day (estimated).
First cost of water-works: $173,000.
Average annual cost of maintenance and repairs: About $3,000.
Number of fire-plugs: 200.

GREENFIELD:

Population: 3,903 inhabitants.
Style of corporation: Municipal
Water obtained from: Brook.
Total area of water-shed available: 3,000 acres.
Capacity of receiving reservoir: 2,000,000 gallons.
Character and dimensions of dam: 60 feet long, 35 feet high, 16 feet broad at base, 12 feet broad on top; solid masonry, built between solid rocks.
Cost of dam: $8,500.
Water first introduced: In 1870.
Description of main conduit: Length 5 miles, diameter 8 and 6 inches; iron, coated.
Discharging capacity: 500,000 gallons; head, 235 feet (average).
Sizes of distributing mains: 4 and 3 inches.
Available head: 80 pounds (average).
Total length of distributing mains: 6 miles.
Number of water-takers: 603.
Consumption of water: 75,000 gallons per day (estimated).
First cost of water-works: $80,000.
Average annual cost of maintenance and repairs: $600.
Number of fire-plugs: 41.

HINGHAM:

Population: 4,485 inhabitants.
Name of corporation: Hingham Water Company (private).
Water obtained from: Accord pond.
Total area of water-shed available: 365 acres.
Character and dimensions of dam: 250 feet long, 2 feet thick through middle, 8 feet high above bottom of conduit; two waste-ways, 7 and 10 feet wide; earthwork with concrete stop-water.
Cost of dam: $3,000.
Water first introduced: June, 1880.
Description of main conduit: Part 1—diameter 16 inches; cast iron; part 2—length 2½ miles, diameter 14 inches; part 3—length 3 miles, diameter 12 inches; wrought iron, cement-lined.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 75 to 120 feet.
Total length of distributing mains: About 14 miles.
Number of water-takers: 250.
First cost of water-works: $80,000.
Average annual cost of maintenance and repairs: $2,200.
Filtering system: Water screened through copper screen, ¼-inch mesh; cleaned yearly.
Number of fire-plugs: 75.

HOLYOKE:

Population: 21,915 inhabitants.
Name of corporation: Holyoke Water-Works (municipal).
Water obtained from: Mountain lakes.

HOLYOKE—Continued.

Total area of water-shed available: 1,726 acres.
Character and dimensions of dam: 401 yards of stone masonry; 7 feet above natural level of lakes at overflow.
Cost of dam: $14,000.
Water first introduced: August, 1873.
Description of main conduit: Part 1—length 1,647 feet, diameter 20 inches; part 2—length 17,332 feet, diameter 16 inches; cast iron.
Discharging capacity: 2,266,000 gallons.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 171 feet (average); water-supply sometimes deficient.
Total length of distributing mains: About 22 miles.
Consumption of water: 75 to 80 gallons per head per day (estimated).
Average annual cost of maintenance and repairs: About $4,000.
Number of fire-plugs: 150.

LEOMINSTER:

Population: 5,772 inhabitants.
Style of corporation: Municipal.
Water obtained from: Morse brook.
Total area of water-shed available: 1,215 acres.
Area and capacity of receiving reservoirs: 85 acres; 160,000,000 gallons; total of 3 reservoirs.
Character and dimensions of dams: No. 1—698 feet long, 15 feet high, 22 feet wide on top; gravel, with cement-laid stone priming wall; face 2 to 1, paved with cobbles. No. 2—304 feet long, 23 feet high; same material as No. 1. No. 3—200 feet long, 12 feet high, 12 feet wide on top; common gravel bank.
Cost of dams: Nos. 1 and 2, $25,000; No. 3, $4,000.
Water first introduced: December, 1873.
Description of main conduit: Length 1½ mile, diameter 12 inches; wrought-iron cement-lined.
Description of distributing reservoir: Area, 5 acres; capacity, 10,000,000 gallons; in a ravine between two abrupt rises of land; dam, 304 feet long and 23 feet high.
Sizes of distributing mains: 12 to 4 inches.
Available head: 175 feet (average).
Total length of distributing mains: 18 miles.
Number of water-takers: 510.
Consumption of water: 60 gallons per head per day.
First cost of water-works: $170,000.
Average annual cost of maintenance and repairs: $1,683 48.
Number of fire-plugs: 109.

MALDEN:

Population: 12,017 inhabitants.
Name of corporation: Malden Water-Works (municipal).
Water obtained from: Spot pond.
Total area of water-shed available: 1,100 acres.
Area and capacity of receiving reservoirs: 296 acres; 1,600,000 gallons.
Character and dimensions of dam: 25 feet wide; stone.
Cost of dam: $1,000.
Water first introduced: In 1870.
Sizes of distributing mains: 16, 12, 8, 6, 4, and 2 inches.
Available head: 125 feet (average); water-supply deficient on highest lands.
Total length of distributing mains: 35 miles.
Number of water-takers: 2,500.
Consumption of water: 40 gallons per head per day (estimated).
First cost of water-works: $350,000.
Average annual cost of maintenance and repairs: $4,000.
Number of fire-plugs: 196.

MEDFORD:

Population: 7,573 inhabitants.
Name of corporation: Medford Water-Works (municipal).
Water obtained from: Spot pound.
Total area of water-shed available: About 1,100 acres.
Area and capacity of receiving reservoir: 296 acres; 1,600,000 gallons.

MEDFORD—Continued.

Character and dimensions of dam: 25 feet wide; stone.
Cost of dam: $2,500.
Water first introduced: In 1870.
Description of main conduit: Diameters, 14 and 12 inches; iron, cement-lined, and Scotch clay.
Sizes of distributing mains: 12 to 4 inches.
Available head: 143 feet (average).
Total length of distributing mains: About 33 miles.
Number of water-takers: About 1,600.
Consumption of water: 500,000 gallons daily (estimated).
First cost of water-works: $300,000.
Average annual cost of maintenance and repairs: About $3,000.
Number of fire-plugs: 150.

MELROSE:

Population: 4,560 inhabitants.
Name of corporation: Melrose Water-Works (municipal).
Water obtained from: Spot pond.
Total area of water-shed available: 1,100 acres.
Area and capacity of receiving reservoir: 296 acres; 1,600,000 gallons.
Character and dimensions of dam: 25 feet wide; granite; overflow when full.
Cost of dam: $2,500.
Water first introduced: In 1870.
Description of main conduit: Length 6,364 feet, diameter 16 inches; wrought iron and cement.
Description of distributing reservoir: Natural; 140 feet above marsh-level.
Sizes of distributing mains: 6 and 4 inches.
Available head: About 80 feet (average). Water supply sometimes deficient on high ground.
Total length of distributing mains: About 16 miles.
Number of water-takers: 980.
First cost of water-works: $60,000.
Average annual cost of maintenance and repairs: $2,500.
Number of fire-plugs: 85.

NORTHAMPTON:

Population: 12,172 inhabitants.
Name of corporation: The Northampton Water-Works (municipal).
Water obtained from: Roberts' Meadow brook.
Total area of water-shed available: 9.24 square miles.
Area, capacity, and description of receiving reservoir: 3 acres; 7,000,000 gallons; depends on flow of brook; western and northern sides of granite and gravel; southern and eastern sides of earth, with puddled center wall 400 feet long.
Character and dimensions of dam: 50 feet wide; 14 feet high; parapets, 5 feet above; rubbled stone.
Cost of dam: $12,913 40.
Water first introduced: In 1871.
Description of main conduit: Length, part, 2½ miles, diameter 16 inches; and part, 2½ miles, diameter 12 inches; cast iron, coated with coal-pitch varnish—leaded joints.
Discharging capacity: 2,350,000 gallons in 24 hours; head, 244 feet (average).
Description of distributing reservoir: Area, 3 acres; capacity, 7,000,000 gallons.
Sizes of distributing mains: 6, 4, 3, etc., inches.
Available head: 186 to 209 feet.
Total length of distributing mains: About 22 miles.
Number of water-takers: 1,224.
Consumption of water: 65 gallons per head per day (estimated).
First cost of water-works: $173,117 45.
Average annual cost of maintenance and repairs: $2,194 88.
Filtering apparatus: Three copper-wire screens.
Number of fire-plugs: 136.

NORTHFIELD:

Population: 1,603 inhabitants.
Name of corporation: Northfield Aqueduct Company (private).

NORTHFIELD—Continued.
Water obtained from: Small brook.
Water first introduced: In 1805.
Description of main conduit: 1¼ mile long; diameter, 2 inches; bored logs.
Size of distributing mains: 1 inch.
Total length of distributing mains: 1¼ mile.
Number of water-takers: 12.
Average annual cost of maintenance and repairs: $7 to $8.

PEABODY:
Population: 9,028 inhabitants.
Name of corporation: Salem and Danvers Aqueduct Company (municipal).
Water obtained from: Spring and Brown pond.
Cost of dam: $178,296.
Water first introduced: In 1797.
Description of main conduit: 1st, diameter 16 inches, cement; 2d, diameter 12 inches, iron.
Discharging capacity: 1,250,000 gallons per day; head, 54 feet (average).
Sizes of distributing mains: 10 to 4 inches.
Available head: 10 to 40 feet; water-supply sometimes deficient.
Total length of distributing mains: Old pipe, unknown; new pipe, 23,500 feet.
Number of water-takers: 1,233.
Consumption of water: 1,000,000 gallons per day (estimated).
First cost of water-works: $125,000.
Average annual cost of maintenance and repairs: $2,500.
Number of fire-plugs: 55.

PITTSFIELD:
Population: 13,364 inhabitants.
Style of corporation: Municipal.
Water obtained from: Ashley lake and Ashley and Sackett brooks.
Capacity of receiving reservoirs: 1,100,000 gallons.
Character and dimensions of dams: No. 1—40 feet wide, 8 feet thick, 8 feet high; rough stone, sheathed with chestnut plank. No. 2—At outlet of Ashley lake, 20 feet wide, 6 feet thick, 10 feet high; cemented.
Cost of dams: $25,000.
Water first introduced: In 1855.
Description of main conduit: One part, length 3 miles, diameter 12 inches; the other part, length 2 miles, diameter 10 inches; iron.
Sizes of distributing mains: 10, 8, 6, 4, 3, 2, and 1½ inches.
Available head: 128 feet (average); water-supply deficient sometimes in hot weather.
Total length of distributing mains: About 20 miles.
Number of water-takers: 1,600.
Consumption of water: 1,000,000 gallons per day (average).
First cost of water-works: $50,000.
Average cost of maintenance and repairs: $1,800.
Filtering apparatus: Water is run through wire screens.
Number of fire-plugs: 75.

SOUTH ADAMS:
Population: 5,593 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs.
Capacity of receiving reservoir: About 3,000,000 gallons.
Character and dimensions of dam: 60 feet long, 12 feet high; stone and cement.
Cost of dam: $125,000.
Water first introduced: In 1873.
Description of main conduit: Diameter, 12 inches; iron.
Sizes of distributing mains: 12, 8, 6, 4, ½, and ¼ inches.
Available head: 30 to 70 pounds per square inch.
Total length of distributing mains: About 6 miles.
Number of water-takers: 615.
First cost of water-works: $110,000.
Average annual cost of maintenance and repairs: $600.

SOUTH ADAMS—Continued.
Filtering apparatus: The water passes through gravel and sand before it enters the main.
Number of fire-plugs: 118.

SOUTHBRIDGE:
Population: 6,464 inhabitants.
Name of corporation: Southbridge Water-Supply Company (private).
Water obtained from: Brook and surface-water.
Total area of water-shed available: 179 acres.
Character and dimensions of dam: 240 feet long, 18 feet high, 57 feet base, 10 feet wide on top; earth, with stone battered on pond side, 6 feet thick at highest point, 8 feet thick at base.
Cost of dam: $15,000.
Water first introduced: November, 1880.
Description of main conduit: 12-inch, cast iron; runs through the dam, with cut-off.
Description of distributing reservoir: A long basin, narrow and deep, covering only 3 acres.
Sizes of distributing mains: 12, 10, 8, and 6 inches.
Available head: 30 to 115 feet; water-supply deficient in some parts of the village.
Total length of distributing mains: 6,800 feet.
Number of fire-plugs: 10.

SOUTH HADLEY FALLS:
Population: 2,750 inhabitants.
Name of corporation: South Hadley Falls Water-Works (municipal).
Water obtained from: Springs.
Total area of water-shed available: 1 acre.
Character and dimensions of dam: 200 feet long, 8 feet high; earth, with 3-inch plank in center.
Cost of dam: $2,000.
Water first introduced: In 1872.
Description of main conduit: Length 3,840 feet, diameter 12 inches; length 3,240 feet, diameter 10 inches; length 1,632 feet, diameter 8 inches; and length 14,784 feet, diameter 4 inches; cast iron.
Available head: 50 to 120 feet.
Number of water-takers: 230.
First cost of water-works: $55,716 65.
Average annual cost of maintenance and repairs: $300.
Number of fire-plugs: 50.

STOCKBRIDGE:
Population: 733 inhabitants.
Name of corporation: Stockbridge Water Company (private).
Water obtained from: Springs.
Total area of water-shed available: 500 acres.
Character and dimensions of dam: 100 feet long, 12 feet high; stone.
Cost of dam: $14,000.
Water first introduced: In 1862.
Description of main conduit: Length, 2 miles; diameter, 4 inches; iron.
Size of distributing mains: 3 inches.
Available head: 70 feet (average); water-supply sometimes deficient.
Total length of distributing mains: 3 miles.
Number of water-takers: 100.
First cost of water-works: About $20,000.
Average annual cost of maintenance and repairs: About $100.
Description of filtering apparatus: Built of brick; 15 feet long, 10 feet wide, 14 feet deep; filled with alternate layers of perforated tile, and charcoal and gravel.
Number of fire-plugs: 1.

WESTBOROUGH:
Population: 5,214 inhabitants.
Name of corporation: Westborough Water-Works (municipal).
Water obtained from: Brook.
Total area of water-shed available: 1,225 acres.

WESTBOROUGH—Continued.
Cost of dam: About $5,000.
Water first introduced: July, 1879.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 133 feet (average).
Total length of distributing mains: 35,019⅚ feet.
Number of water-takers: 240.
First cost of water-works: $53,000.
Average annual cost of maintenance and repairs: $400.
Number of fire-plugs: 57.

WESTFIELD:
Population: 7,587 inhabitants.
Name of corporation: Westfield Water-Works (municipal).
Water obtained from: Brook.
Total area of water-shed available: 4¼ square miles.
Capacity of receiving reservoir: 184,000,000 gallons.
Character and dimensions of dams: No. 1—350 feet long, 30 feet high, 20 feet wide on top; earth embankment, with cement wall 8 feet thick above foundation, 3 feet thick at top, 2 feet above water-line. No. 2—193 feet long, 28 feet high, 14½ feet thick at base, 7 feet thick at top; bulkhead of cut-off wall across bottom, 50 feet down main wall.
Cost of dams: $42,000.
Water first introduced: In 1874.
Description of main conduit: Length 4½ miles, diameter 14 inches; cast iron.
Capacity of distributing reservoir: 4,064,000 gallons.
Sizes of distributing mains: 10, 8, 6, and 4 inches.
Available head: 120 pounds per square inch; head, 291 feet (average).
Total length of distributing mains: About 16 miles.
Number of water-takers: 696.
First cost of water-works: $250,000.
Average annual cost of maintenance and repairs: $1,250.
Number of fire-plugs: 115.

WEST SPRINGFIELD:
Population: 4,149 inhabitants.
Name of corporation: West Springfield Aqueduct Company (private).
Water obtained from: Small stream.
Total area of water-shed available: About 300 acres.
Character and dimensions of dam: 450 feet long on top, 18 feet high (center), 20 feet wide on top; slope inside, 4 to 1; lower side, 1 to 1; earth, clay, and sand; center puddle all the way up, with dike of clay.
Cost of dam: $6,000.
Water first introduced: October, 1875.
Description of main conduit: Diameter, 16 inches; wrought iron, cement-lined.
Sizes of distributing mains: 8 and 6 inches.
Available head: 90 feet (average).
Total length of distributing mains: About 6 miles.
Number of water-takers: 170.
First cost of water-works: $50,000.
Number of fire-plugs: 15.

WEST STOCKBRIDGE:
Population: 1,923 inhabitants.
Name of corporation: East Mountain Water Company (private).
Water obtained from: Spring.
Character and dimensions of dam: 10 or 15 feet long, 6 feet high, 2 feet thick; stone laid in cement.
Cost of dam: $200.
Water first introduced: In 1873.
Description of main conduit: Part length 500 feet, diameter 2 inches; part length 3,500 feet, diameter 1½ inch; wrought-iron gas-pipe.
Size of distributing mains: ½ inch.
Available head: 160 feet (average).
Total length of distributing mains: 2,100 feet (estimated).
Number of water-takers: 31.

WEST STOCKBRIDGE—Continued.
Consumption of water: 25 gallons per day per family (estimated).
First cost of water-works: About $2,300.
Average annual cost of maintenance and repairs: $10.

WILLIAMSTOWN:
Population: 984 inhabitants.
Name of corporation: Williams Aqueduct Company (private).
Water obtained from: Springs.
Capacity of receiving reservoir: 1,764 gallons.
Cost of dam: $75 to $100.
Water first introduced: In 1862.
Description of main conduit: Length 1¾ mile, diameter 6 to 3 inches; cast iron.
Sizes of distributing mains: 6 and 3 inches.
Available head: 20 to 40 feet.
Total length of distributing mains: About 2 miles.
Number of water-takers: 75.
First cost of water-works: $12,000.
Average annual cost of maintenance and repairs: $20.
Number of fire-plugs: 4.

WINCHESTER:
Population: 3,802 inhabitants.
Style of corporation: Municipal.
Water obtained from: Water-shed.
Total area of water-shed available: About 460 acres.
Capacity of receiving reservoir: 259,000,000 gallons.
Character and dimensions of dam: 120 feet wide at bottom, 30 feet high; stone wall in cement in center 2½ to 1½ feet thick; earth; overflow, 34 feet wide; gate-house of brick and stone, with waste-gate 30 inches; supply, 18 inches.
Cost of dam: $41,573.
Water first introduced: July, 1874.
Description of main conduit: Length, 1,500 feet; diameter, 12 inches; wrought iron, cement-lined.
Sizes of distributing mains: 12, 10, 8, 6, 4, and 2 inches.
Available head: 123 feet (average); water-supply sometimes deficient.
Total length of distributing mains: About 18 miles.
Number of water-takers: About 630.
Consumption of water: 70,000 to 90,000 gallons daily (variable), by measurement.
First cost of water-works: $160,000.
Average annual cost of maintenance and repairs: $1,500 to $1,700.
Number of fire-plugs: 73.

WORCESTER:
Population: 58,291 inhabitants.
Name of corporation: Worcester City Water-Works (municipal).
Water obtained from: Lynde lake.
Total area of water-shed available: 1,727 acres.
Capacity of receiving reservoir: 681,827,000 gallons.
Character and dimensions of dams: Main dam, 550 feet long, 50 feet high, 225 feet base, 50 feet wide on top; earth, with puddle-wall and mortar-wall. Side dam, 1,400 feet long, 115 feet base, 20 feet high, 45 feet wide on top; earth, with mortar-wall in center.
Cost of dams: $1,273,068 10.
Water first introduced: In 1864.
Description of main conduit: Cast iron; wrought iron, cement-lined.
Discharging capacity: 3,800,000 gallons per day; head, 150 feet (average).
Description of distributing reservoir: Partly excavation and partly embankment; capacity, 3,000,000 gallons.
Sizes of distributing mains: 24 to 3 inches.
Available head: About 60 pounds (average).
Total length of distributing mains: 80 miles.
Number of water-takers: 40,000.
Consumption of water: 3,000,000 gallons per day (estimated).
First cost of water-works: $17,699 60
Number of fire-plugs: 633.

UXBRIDGE:
Population: 3,111 inhabitants.
Name of corporation: Uxbridge Water Company (private).
Water obtained from: Spring.
Cost of dam: $6,000.
Water first introduced: In 1880.
Description of main conduit: Part length 2,136$\frac{3}{12}$ feet, diameter 6 inches; part length 594½ feet, diameter 4 inches; tarred iron pipe.
Size of distributing mains: 1 inch.
Available head: 135 feet (average).
Number of water-takers: 11.
First cost of water-works: $3,800.
Number of fire-plugs: 1.

MICHIGAN.

NILES:
Population: 4,197 inhabitants.
Name of corporation: Niles Water-Works (private).
Water obtained from: Berrien lake.
Area and capacity of receiving reservoir: 1 mile long, ½ mile wide; 300,000 gallons.
Cost of dam: $4,500.
Water first introduced: July, 1879.
Description of main conduit: 5 miles long, 12 inches diameter; iron.
Description of stand-pipe: 37 feet deep, 36 feet in diameter; built of boiler-iron.
Sizes of distributing mains: 12 and 6 inches.
Available head: 75 to 100 feet.
Total length of distributing mains: About 10 miles.
Number of water-takers: 125.
Consumption of water: 100 gallons per head per day (estimated).
First cost of water-works: $50,000.
Number of fire-plugs: 50.

MINNESOTA.

SAINT PAUL:
Population: 41,473 inhabitants.
Name of corporation: Saint Paul Water Company (private).
Water obtained from: Lakes.
Total area of water-shed available: 60,000 acres.
Area of receiving reservoir: 1,800 acres.
Cost of dam: $10,000 to $15,000.
Water first introduced: In 1869.
Description of main conduit: Part length 1½ mile, diameter 24 inches, glazed earthenware; part length 1½ mile, diameter 16 inches, cement and gravel.
Discharging capacity: 7,000,000 gallons per day.
Description of distributing reservoir: Lake; area, 220 acres.
Sizes of distributing mains: 16, 12, 6, and 4 inches.
Available head: 165 feet (average).
Total length of distributing mains: 22 miles.
Number of water-takers: 1,850.
Consumption of water: 25 gallons per head per day (estimated).
First cost of water-works: $290,000.
Average annual cost of maintenance and repairs: About $8,000.
Number of fire-plugs: 188.

NEVADA.

AUSTIN:
Population: 1,679 inhabitants.
Name of corporation: Austin City Water-Works (private).
Water obtained from: Springs.
Total area of water-shed available: 50 acres.
Cost of dam: $7,000.
Water first introduced: In 1865.
Description of main conduit: Length 7,200 feet, diameter 3½ inches; galvanized iron.
Discharging capacity: 15 to 20 gallons per minute.
Description of distributing reservoir: Capacity, 50,000 gallons; brick, cemented.

AUSTIN—Continued.
Sizes of distributing mains: 6, 2½, 2, 1, and ¾ inches.
Available head: 80 to 125 pounds per square inch; water-supply deficient in July and August.
Total length of distributing mains: 4,025 feet.
Number of water-takers: 270.
Consumption of water: 15,000 to 18,000 gallons per day (estimated).
Number of fire-plugs: 15.

EUREKA:
Population: 4,207 inhabitants.
Style of corporation: Private.
Water obtained from: Springs.
Total area of water-shed available: 40 square miles.
Capacity of receiving reservoir: 240,000 gallons.
Cost of dam: $8,000.
Water first introduced: In 1871.
Description of distributing reservoir: Tanks, of lumber, set under and above ground.
Size of distributing mains: 6 inches.
Available head: 92 feet (average).
Total length of distributing mains: 4 miles.
Number of water-takers: 500.
Consumption of water: 20 gallons per head daily (estimated).
Number of fire-plugs: 20.

PIOCHE:
Population: 745 inhabitants.
Name of corporation: Floral Springs Water-Works (private).
Water obtained from: Springs.
Capacity of receiving reservoir: 60,000 gallons.
Water first introduced: In 1872.
Description of main conduit: Length 400 feet, diameter 5 inches; sheet iron.
Description of distributing reservoir: Capacity, 150,000 gallons.
Size of distributing mains: 5 inches.
Available head: 112 feet (average).
Total length of distributing mains: About 7 miles.
Number of water-takers: About 50.
Consumption of water: 10 gallons per head daily (estimated).
First cost of water-works: $200,000.
Average annual cost of maintenance and repairs: $7,500.
Number of fire-plugs: 20.

RENO:
Population: 1,302 inhabitants.
Name of corporation: Reno Water Company (private).
Water obtained from: Truckee river.
Cost of dam: $3,500.
Water first introduced: August, 1879.
Description of distributing reservoir: Located on a flat point of land, crescent shape; area, 5½ acres; 10 feet deep; 200 feet above town.
Sizes of distributing mains: 24 to 8 inches.
Total length of distributing mains: About 5 miles.
Number of water-takers: 400.
First cost of water-works: $15,000 to $18,000.
Average annual cost of maintenance and repairs: $1,500 to $2,000.

VIRGINIA CITY:
Population: 10,917 inhabitants.
Name of corporation: Virginia City and Gold Hill Water Company (private).
Water obtained from: Lakes.
Total area of water-shed available: 25 square miles.
Capacity of receiving reservoir: 30,000,000 cubic feet.
Character and dimensions of dams: No. 1—260 feet long, 30 feet high; earth and timber. No. 2—180 feet long, 38 feet high; cemented rock wall.
Cost of dams: $89,000.
Water first introduced: August, 1873.
Description of main conduit: Part 16 miles long, 18 by 16½ wide; 1½-inch plank. Part 7 miles long, diameter 12 inches; riveted iron. Part 7 miles long, diameter 10 inches; lap-welded iron.

VIRGINIA CITY—Continued.

Discharging capacity: 4,500,000 gallons per day; head, 465 feet (average).
Description of distributing reservoirs: 13 tanks, situated 180 feet above town; distributed through about 2 miles.
Sizes of distributing mains: 4 inches to 1 inch.
Available head: 180 feet (average).
Total length of distributing mains: About 19 miles.
Number of water-takers: About 2,300.
Consumption of water: 110 gallons per head daily (estimated).
First cost of water-works: $1,780,000.
Average annual cost of maintenance and repairs: About $30,000.
Filtering apparatus: Cleaned once a year.
Number of fire-plugs: 91.

NEW HAMPSHIRE.

BETHLEHEM:

Population: 1,400 inhabitants.
Name of corporation: Crystal Springs Water Company (private).
Water obtained from: Several large springs.
Capacity of receiving reservoir: 250,000 gallons.
Cost of dam: $14,000.
Water first introduced: In 1879.
Description of main conduit: Diameters, 6 and 3 inches; wrought and cast iron, tarred.
Description of distributing reservoir: One side solid ledge, one side masonry, and two sides railroad embankment.
Size of distributing mains: 6 inches.
Available head: 150 feet (average).
Total length of distributing mains: 6,000 feet.
Number of water-takers: 40.
Consumption of water: 150,000 gallons per day (estimated).
First cost of water-works: $10,000.
Average annual cost of maintenance and repairs: About $300.
Number of fire-plugs: 6.

DOVER:

Population: 11,687 inhabitants.
Style of corporations: Private; three.
Water obtained from: Springs and ponds.
Water first introduced: In 1824.
Description of main conduit: Diameter, 6 inches; cast iron.
Available head: 40 feet (average); water-supply not often deficient.

HANOVER:

Population: 1,134 inhabitants.
Name of corporation: Hanover Aqueduct Association (private).
Water obtained from: Springs.
Water first introduced: In 1822.
Description of main conduit: Length 2 miles, diameter 2 inches; lead.
Discharging capacity: 12,600 gallons per day; head, 50 to 100 feet.
Sizes of distributing mains: 1¾, 1½, 1¼, and 1 inch.
Available head: 60 to 70 feet; water-supply sometimes deficient.
Number of water-takers: About 170.
Consumption of water: 7,000 gallons per day (estimated).
First cost of water-works: About $7,000.
Average annual cost of maintenance and repairs: $50 to $100.

KEENE:

Population: 6,784 inhabitants.
Name of corporation: Keene Water-Works (municipal).
Water obtained from: Ponds.
Total area of water-shed available: About 1,900 acres.
Area and capacity of receiving reservoir: Pond area, 53 acres; 135,000,000 gallons.
Character and dimensions of dams: 1st, 300 feet long, 8 feet high, earth; main dam, 150 feet long, 20 feet high, center wall laid in cement, sloped with earth, water-side paved with stone; dam at reservoir, 225 feet long, 22 feet high.
Cost of dams: $20,000.
Water first introduced: In 1869.

KEENE—Continued.

Description of main conduit: Part length 500 feet, diameter 16 inches; part length 500 feet, diameter 14 inches; part length 2½ miles, diameter 12 inches; mostly cement.
Discharging capacity: 12 inches diameter; head, 130 feet (average).
Sizes of distributing mains: 10, 8, 6, 4, and 2 inches.
Available head: 58 pounds or 150 feet (average).
Total length of distributing mains: About 25 miles.
Number of water-takers: 764.
First cost of water-works: $168,699 58.
Average annual cost of maintenance and repairs: $1,200.
Number of fire-plugs: 121.

PORTSMOUTH:

Population: 9,690 inhabitants.
Name of corporation: Portsmouth Water Company (private).
Water obtained from: 20 bubbling springs.
Water first introduced: In 1797.
Description of main conduit: One cement-lined iron pipe, laid in 1868, 2 miles long; one 10-inch wood pipe, laid in 1875, about 3¾ miles long; two other 5-inch wood-pipes (original pipes), 2½ miles long each.
Description of distributing reservoir: Size, 70 by 100 by 10 feet; capacity, 500,000 gallons; two divisions excavated in hill-side; sloping walls inside and outside; hill-side face, 1 foot thick; exposed side-wall, 5 feet base, 3 feet on top.
Sizes of distributing mains: 10, 5, and 4 inches.
Available head: Water-supply deficient during droughts.
Total length of distributing mains: About 16 miles.
Number of water-takers: 2,000.
Consumption of water: 750,000 to 1,000,000 gallons per day.
First cost of water-works: $90,000.

NEW JERSEY.

MORRISTOWN:

Population: 5,418 inhabitants.
Name of corporation: Morris Aqueduct Company (private).
Water obtained from: Springs.
Capacity of receiving reservoir: 20,475,000 gallons.
Character and dimensions of dams: One reservoir, earthwork lined with stone, capacity, 16,380,000 gallons; two smaller stone dams, capacity, 350,000 gallons.
Cost of dams: $44,132.
Water first introduced: In 1799.
Description of main conduit: Diameters, 6 and 4 inches; iron.
Description of distributing reservoir: 130 feet long, 70 feet wide, 14 feet deep; stone wall laid up with cement, 4 feet wide on bottom, 2½ feet wide on top; bottom laid with concrete, faced inside with cement; capacity, 930,000 gallons.
Sizes of distributing mains: 6, 4, 3, and 2 inches.
Available head: 75 feet (average).
Total length of distributing mains: About 12 miles.
Number of water-takers: 550.
Consumption of water: 30 gallons per head daily (estimated).
First cost of water-works: $33,000.
Average annual cost of maintenance and repairs: $2,500.
Filtering apparatus: Gravel and charcoal; cleaned yearly.
Number of fire-plugs: 67.

NEW YORK.

ATTICA:

Population: 1,935 inhabitants.
Style of corporation: Private.
Water obtained from: Crow creek.
Total area of water-shed available: 4 square miles.
Dimensions of receiving reservoir: Length 300 feet, width 40 feet, depth 5½ feet (average).
Character and dimensions of dam: 75 feet long, 11 feet high, average 4 feet thick; stone, faced with brick.
Water first introduced: December, 1879.
Description of main conduit: 1 mile 10-inch iron pipe, 1 mile 8-inch iron pipe, and ¼ mile 6-inch iron pipe.
Sizes of distributing mains: 4 and 3 inches.

ATTICA—Continued.

Available head: 120 feet (average); water-supply deficient in summer.
Total length of distributing mains: 4 miles.
Number of water-takers: 50.
First cost of water-works: About $30,000.
Average annual cost of maintenance and repairs: $50.
Filtering apparatus: Wire screen; cleaned yearly from leaves.
Number of fire-plugs: 20.

AVON:

Population: 1,617 inhabitants.
Name of corporation: Avon Water-Works (private).
Water obtained from: Springs.
Capacity of receiving reservoir: About 2,000,000 gallons.
Cost of dam: $3,000.
Water first introduced: In 1858.
Description of main conduit: Diameter, 4 inches; American wrought iron, cement-covered.
Description of distributing reservoir: 150 by 150 feet, 17 feet deep; banks puddled with clay; embankment, earth; slope, 2 to 1.
Sizes of distributing mains: 3 inches to ½ inch.
Available head: About 50 pounds to square inch (average).
Number of water-takers: About 70.
First cost of water-works: About $15,000.
Average annual cost of maintenance and repairs: $200.
Number of fire-plugs: 10.

DELHI:

Population: 1,384 inhabitants.
Name of corporation: Delhi Water Company (private).
Water obtained from: Steel's brook.
Character and dimensions of dam: 200 feet long; sets back 200 feet; average depth, 6 feet; solid masonry.
Cost of dam: About $5,000.
Water first introduced: In 1872.
Sizes of distributing mains: 6 and 3 inches.
Available head: 85 feet (average).
Total length of distributing mains: Over 2 miles.
Number of water-takers: About 160.
First cost of water-works: $2,600.
Average annual cost of maintenance and repairs: About $100.
Filtering apparatus: Sand and gravel filter in center of dam; water-supply passes through into pipes; cleaned once a year.
Number of fire-plugs: 32.

ELLENVILLE:

Population: 2,750 inhabitants.
Style of corporation: Municipal.
Water obtained from: Mountain brooks.
Total area of water-shed available: 2½ miles by 1 mile.
Dimensions of receiving reservoir: 18 by 25 by 45 feet.
Character of dam: Rock; three sides of stone; wall along creek; reservoir independent of main channel.
Cost of dam: $34,592 85.
Water first introduced: In 1872.
Description of main conduit: Part 5,700 feet long, 8 inches diameter; part 1,400 feet long, 6 inches diameter; part 13,900 feet long, 4 inches diameter; iron.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 140 feet (average).
Total length of distributing mains: 21,000 feet.
Number of water-takers: 129.
First cost of water-works: $33,995 84.
Average annual cost of maintenance and repairs: $588 55.
Number of fire-plugs: 40.

GENEVA:

Population: 5,878 inhabitants.
Name of corporation: The Geneva Water-Works Company (private).
Water obtained from: Springs.
Area and capacity of receiving reservoirs: One 20 feet higher than the other, supplied by springs 150 feet square; lower one, 100 feet diameter; capacities, 2,000,000 and 500,000 gallons.

GENEVA—Continued.

Water first introduced: In 1796.
Description of main conduit: Diameters, 10, 8, 6, and 4 inches; cast iron.
Size of distributing mains: 4 inches.
Available head: 125 to 150 feet.
Total length of distributing mains: About 4 miles.
Consumption of water: 500,000 gallons per day (estimated).
First cost of water-works: $50,000.
Average annual cost of maintenance and repairs: $250.
Number of fire-plugs: 24.

GLENS FALLS:

Population: 4,900 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs.
Total area of water-shed available: About 650 acres.
Capacity of receiving reservoirs: Main one, earth with concrete, 300 feet on top, 52,000,000 gallons. Two small ones, stone, laid in cement, about 4,000,000 gallons each.
Cost of dam: $20,000.
Water first introduced: In 1872.
Description of main conduit: 8 miles long, 12 and 10 inches diameter; sheet iron, cement-lined.
Sizes of distributing mains: 6 and 4 inches.
Available head: 250 feet (average).
Total length of distributing mains: About 7 miles.
Number of water-takers: About 450.
First cost of water-works: $125,000.
Average cost of maintenance and repairs: $650.
Number of fire-plugs: 90.

GLOVERSVILLE:

Population: 7,133 inhabitants.
Name of corporation: Gloversville Water-Works (municipal).
Water obtained from: Springs and mountain brook.
Capacity of receiving reservoirs: No. 1, 3,000,000 gallons; No. 2, 500,000 gallons; No. 3, 1,500,000 gallons.
Character and dimensions of dams: Two of stone and gravel, and one of stone; they rest against hills in each instance.
Cost of dams: $82,756 11.
Water first introduced: In 1877.
Available head: 250 feet (average).
Total length of distributing mains: 6 miles.
Number of water-takers: 500.
Number of fire-plugs: 65.

GOSHEN:

Population: 2,557 inhabitants.
Name of corporation: Goshen Water-Works (municipal).
Water obtained from: Water-sheds and springs.
Total area of water-shed available: 100 acres.
Area and capacity of receiving reservoir: 40 acres; 30 feet deep.
Character and dimensions of dam: 500 feet long 20 feet high, 100 feet at base and 40 feet on top; center puddled.
Cost of dam: $63,000.
Water first introduced: In 1872.
Description of main conduit: Length 1½ mile, diameter 12 inches; sheet iron, lined and covered with cement.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 150 feet (average).
Total length of distributing mains: 6 miles.
Number of water-takers: 144.
First cost of water-works: $40,000.
Average annual cost of maintenance and repairs: $200.
Number of fire-plugs: 70.

MALONE:

Population: 4,193 inhabitants.
Name of corporation: Malone Water-Works Company (private).
Water obtained from: Three springs.
Cost of dam: $1,200.
Water first introduced: In 1857.
Description of main conduit: Length 3 miles, diameter 4 inches; iron, lined with cement.

MALONE—Continued.

Discharging capacity: 50 gallons per minute; head, 90 feet (average).
Description of distributing reservoir: 45 by 90 feet; stone, concrete puddled; covered by shingle roof.
Sizes of distributing mains: 3, 2, and 1½ inches.
Available head: 80 feet (average).
Total length of distributing mains: 4 miles.
Number of water-takers: 436.
First cost of water-works: $40,000.
Average annual cost of maintenance and repairs: $1,200.

MIDDLETOWN:

Population: 8,494 inhabitants.
Name of corporation: Middletown Water-Works (municipal).
Water obtained from: Springs.
Total area of water-shed available: 500 acres.
Area and capacity of receiving reservoir: 350,000,000 gallons.
Character and dimensions of dam: 500 feet long, 15 to 20 feet high; earth and stone.
Cost of dam: $12,000.
Water first introduced: In 1867.
Description of main conduit: 2 miles long, 12 inches diameter, iron; 2 miles long, 10 inches diameter, cement.
Sizes of distributing mains: 10, 8, 6, and 4 inches.
Available head: 50 feet (average).
Total length of distributing mains: 8 miles.
Number of water-takers: 400.
Consumption of water: 1,000,000 gallons per day.
First cost of water-works: $150,000.
Average annual cost of maintenance and repairs: $2,000.
Number of fire-plugs: 88.

MOUNT MORRIS:

Population: 1,899 inhabitants.
Name of corporation: Mills Water-Works Company (private).
Water obtained from: Quicksand springs.
Total area of water-shed available: About 1 square mile.
Capacity of receiving reservoir: 1,025,000 gallons.
Water first introduced: November, 1879.
Description of main conduit: Length 1 mile, diameter 4 inches; cast iron, coated inside and out with asphaltum cement.
Discharging capacity: 106,704 gallons in 24 hours; head, 15 feet (maximum).
Description of distributing reservoir: Size, 80 by 80 feet (bottom), 140 by 140 feet (top); 12 feet 6 inches (maximum) depth of water; face of banks, stone and cement; bottom, 6 inches gravel, concrete, and cement.
Sizes of distributing mains: 10, 8, and 6 inches.
Available head: 30 to 115 feet.
Total length of distributing mains: 3 miles.
Number of water-takers: About 80.
Consumption of water: 20 gallons per head daily (estimated).
First cost of water-works: $30,000.
Number of fire-plugs: 25.

NEWBURG:

Population; 18,049 inhabitants.
Name of corporation: Newburg City Water-Works (municipal).
Water obtained from: Lake.
Total area of water-shed available: 1,000 acres.
Area and capacity of receiving reservoir: About 75 acres; depth, 15 feet (average).
Character and dimensions of dam: Earthworks for increasing capacity of lake.
Cost of dam: $422,014 38.
Water first introduced: In 1854.
Description of main conduit: Length 3,128 feet, diameter 24 inches; length 12,360 feet, diameter 20 inches; cast iron.
Sizes of distributing mains: 12, 8, 6, and 4 inches.
Available head: Water-supply deficient only when pumping to mains is resorted to.
Total length of distributing mains: 13 miles.
Number of water-takers: 2,767.
First cost of water-works: About $107,000.
Average annual cost of maintenance and repairs: $2,000.

PLATTSBURG:

Population: 5,245 inhabitants.
Style of corporation: Municipal.
Water obtained from: Mountain brooks.
Total area of water-shed available: About 20 square miles.
Area and capacity of receiving reservoir: 3 acres; 6 feet deep (average); 3,456,000 gallons.
Water first introduced: In 1870.
Description of main conduit: Length, 2 miles; diameter, 12 inches.
Sizes of distributing mains: 10, 8, 6, 4, and 2 inches.
Available head: 200 feet (average).
Total length of distributing mains: 52,289 feet.
Consumption of water: 1,200,000 gallons per day (estimated).
First cost of water-works: $180,000.
Average annual cost of maintenance and repairs: $2,486.
Number of fire-plugs: 24.

PORT JERVIS:

Population: 8,678 inhabitants.
Name of corporation: Port Jervis Water-Works Company (private).
Water obtained from: Running streams and surface-water.
Total area of water-shed available: About 4,000 acres.
Capacity of receiving reservoir: 200,000,000 gallons.
Character and dimensions of dam: 30 feet high, 20 feet wide on top; slope, 2 to 1 front, 1¾ to 1 back; 6 feet above high-water mark.
Cost of dam: About $40,000.
Water first introduced: In 1870.
Description of main conduit: Length 2 miles, diameter 12 inches; cast iron.
Sizes of distributing mains: 10, 8, 6, and 4 inches.
Available head: About 120 feet (average).
First cost of water-works: About $105,000.
Average annual cost of maintenance and repairs: About $1,500.
Number of fire-plugs: 118.

RICHFIELD SPRINGS:

Population: 1,307 inhabitants.
Name of corporation: Richfield Springs Water-Works (municipal).
Water obtained from: Springs and surface-water.
Total area of water-shed available: About 1,000 acres.
Capacity of receiving reservoirs: No. 1—1,000,000 gallons. No. 2—7,000,000 gallons.
Character and dimensions of dam: 300 feet long; at bottom, 150 feet; 25 feet high; puddled in center, and made in a semicircle.
Water first introduced: October, 1879.
Description of main conduit: Length 1,200 feet, diameter 10 inches; vitrified pipe.
Size of distributing mains: 10 inches.
Available head: 15 to 180 feet.
Total length of distributing mains: About 3 miles.
Number of water-takers: About 20.
First cost of water-works: $22,500.
Average annual cost of maintenance and repairs: About $300.
Number of fire-plugs: 23.

UTICA:

Population: 33,914 inhabitants.
Name of corporation: Utica Water-Works Company (private).
Water obtained from: Graefenburg springs and Starch Factory creek.
Total area of water-shed available: About 2,000 acres.
Area and capacity of receiving reservoirs: Graefenburg river—7 acres; 35,000,000 gallons. Starch Factory creek—26 acres; 28,000,000 gallons.
Character and dimensions of dams: Graefenburg dam—400 feet long (top); 55 feet high; slope, 1½ to 1 outside, 2 to 1 inside. Starch Factory Creek dam—540 feet long; 20 feet wide; 70 feet high; slope, 1½ to 1 outside, 2 to 1 inside; all earth. Distributing reservoir dam—660 feet long, 10 feet wide, 28 feet high.
Cost of dams: $500.
Water first introduced: In 1849.

UTICA—Continued.

Description of main conduit: 1 mile long; diameter, 12 inches, brick; diameters 20 and 12 inches, iron.
Description of distributing reservoir: Area, 9 acres; capacity, 30,000,000 gallons; water taken from surface by movable flume into well, thence to city.
Sizes of distributing mains: 12, 10, 8, 6, 5, 4, and 3 inches.
Available head: 15 to 16 pounds.
Total length of distributing mains: About 30 miles.
Number of water-takers: About 1,200.
Consumption of water: 125,000 gallons per day (estimated).
First cost of water-works: $75,000.
Average annual cost of maintenance and repairs: $5,000.
Number of fire-plugs: 200.

WALTON:

Population: 1,389 inhabitants.
Name of corporation: Walton Water Company (private).
Water obtained from: Brook fed by springs.
Total area of water-shed available: 4 square miles.
Area and capacity of receiving reservoir: 2½ acres; 12,000,000 gallons.
Character and dimensions of dam: 140 feet long, 96 wide (bottom), 20 feet wide (top), 24 feet high; weir, 60 feet long, 20 feet high.
Cost of dam: $3,279.
Water first introduced: September, 1879.
Description of main conduit: 150 feet long, 10 inches diameter; 8,814 feet long, 8 inches diameter; cast iron.
Description of distributing reservoir: Area, 2½ acres; capacity, 12,000,000 gallons.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 206 feet (average).
Total length of distributing mains: 3 7/10 miles.
Number of water-takers: 61.
Consumption of water: 40,000 gallons per day (estimated).
First cost of water-works: $17,000.
Average annual cost of maintenance and repairs: $10.
Filtering system: Size, 12 feet deep, 9 feet long, divided into three compartments by wire screens filled with charcoal and sponges; cleaned every four months.
Number of fire-plugs: 22.

WARSAW:

Population: 1,910 inhabitants.
Name of corporation: Warsaw Water-Works Company (private).
Water obtained from: Springs and brooks.
Total area of water-shed available: 3½ square miles.
Capacity of receiving reservoirs: 300,000 and 600,000 gallons.
Cost of dam: $1,500.
Water first introduced: In 1870.
Description of main conduit: Length 2½ miles, diameter 4 inches; iron.
Discharging capacity: 10,000 gallons per day; head, 70 feet (average).
Description of distributing reservoir: 60 feet square, 18 feet deep.
Size of distributing mains: 4 inches.
Available head: 275 feet (average).
Total length of distributing mains: 6 miles.
Number of water-takers: 250.
Consumption of water: 4,000 gallons daily (estimated).
First cost of water-works: $18,000.
Average annual cost of maintenance and repairs: $200.
Filtering apparatus: Cleaned every five years.
Number of fire-plugs: 26.

WARWICK:

Population: 1,043 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs and small stream.
Total area of water-shed available: About 3 square miles.
Capacity of receiving reservoir: 2,500,000 gallons.
Character and dimensions of dam: 70 feet long, 30 feet high, 70 feet wide at bottom, 20 feet wide on top; puddled earth faced with stone.

WARWICK—Continued.

Cost of dam: $5,000.
Water first introduced: In 1871.
Description of main conduit: Length 100 feet, diameter 12 inches, cast iron; length 1½ mile, diameter 8 inches; length 1¼ mile, diameter 6 and 4 inches; sheet iron lined with cement.
Sizes of distributing mains: 12, 8, 6, and 4 inches.
Available head: 120 feet (average).
Total length of distributing mains: 2¾ miles.
Number of water-takers: 80.
First cost of water-works: $25,000.
Average annual cost of maintenance and repairs: $50.
Number of fire-plugs: 30.

WAVERLY:

Population: 2,767 inhabitants.
Name of corporation: Waverly Water Company (private).
Water obtained from: Water-shed.
Total area of water-shed available: 2 square miles.
Capacity of receiving reservoir: 95,000,000 gallons.
Character and dimensions of dam: 60 feet high, 220 feet wide (bottom), 10 feet wide (top); slope, 1½ to 1 back, 2 to 1 front; stone wall in center 35 feet high, 8 feet at bottom, 4 feet at top; earth.
Cost of dam: About $15,000.
Water first introduced: December, 1880.
Description of main conduit: Diameter, 12 inches; cast iron.
Discharging capacity: 4,000,000 gallons per day; head, 190 feet (average).
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 200 feet (average).
Total length of distributing mains: 5 miles.
First cost of water-works: About $50,000.
Number of fire-plugs: 18.

NORTH CAROLINA.

FAYETTEVILLE:

Population: 3,485 inhabitants.
Name of corporation: Fayetteville Water-Works (private).
Water obtained from: 4 springs.
Total area of water-shed available: 200 square feet.
Water first introduced: About 1819.
Description of main conduit: Diameter, 3 inches; bored pine logs.
Description of distributing reservoir: Size, 8 by 12 feet, and 6 feet pitch; brick house.
Size of distributing mains: 2 inches.
Available head: 30 to 40 feet; water-supply often deficient.
Total length of distributing mains: About 2 miles.
Average annual cost of maintenance and repairs: $150 to $200.
Number of fire-plugs: 8.

OHIO.

NEW LISBON:

Population: 2,028 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs and small stream.
Total area of water-shed available: About 200 acres.
Character and dimensions of dam: 60 feet long (on top), 20 feet high; built across ravine, of stone, grouted; fed from springs.
Cost of dam: $2,000.
Water first introduced: About 1841.
Description of main conduit: Diameter, 10 inches; wooden pipe.
Sizes of distributing mains: 6 and 4 inches.
Available head: About 100 feet (average); water-supply deficient in dry seasons.
Total length of distributing mains: About 2 miles.
Number of water-takers: 26.
Average cost of maintenance and repairs: $50 to $80.
Number of fire-plugs: 21.

WOOSTER:

Population: 5,840 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs and surface-water.

WOOSTER—Continued.

Total area of water-shed available: About 700 acres.

Character and dimensions of dams: Main—breast, 300 feet long, 18 feet high, capacity, 5,000,000 gallons; 500 feet from this is a dam 200 feet long, 15 feet high, to arrest storm-water which passes through a 12-inch pipe under the main dam.

Cost of dams: $11,000.

Water first introduced: In 1876.

Description of main conduit: Diameter, 12 inches; cast iron.

Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.

Available head: 50 to 160 feet; water-supply sometimes deficient.

Total length of distributing mains: About 8½ miles.

Number of water-takers: 175.

First cost of water-works: $80,000.

Average annual cost of maintenance and repairs: About $500.

Number of fire-plugs: 88.

OREGON.

DALLAS:

Population: 2,232 inhabitants.

Name of corporation: Dallas Water-Works (private).

Water obtained from: Mountain streams.

Total area of water-shed available: 100 square miles.

Area and capacity of receiving reservoirs: No. 1, 16 by 200 feet; built of stone. No. 2, 90 by 80 feet; three sides natural stone walls, fourth side earth and timber.

Description of dam: 13 feet high.

Cost of dam: $1,500.

Water first introduced: In 1862.

Description of main conduit: Length 1½ mile, diameters 10 and 8 inches; red-fir timber, 1½ inch thick.

Discharging capacity: 55,000 gallons per hour; head, 22 feet (average).

Description of distributing reservoir: Located on a perpendicular precipice of rock; 102 feet elevation; area, 16 by 20 feet; 8 feet deep.

Sizes of distributing mains: 8 and 4 inches.

Available head: 40 feet (average).

Total length of distributing mains: 14,000 feet.

Number of water-takers: 400.

Consumption of water: 51 gallons per head per day (estimated).

First cost of water-works: $12,000.

Average annual cost of maintenance and repairs: $2,500.

Number of fire-plugs: 6.

PENNSYLVANIA.

ALTOONA:

Population: 19,710 inhabitants.

Name of corporation: Altoona City Water-Works (municipal).

Water obtained from: Base of Alleghany mountains.

Capacity of receiving reservoir: 100,000,000 gallons.

Cost of dam: $300,000.

Water first introduced: April or May, 1872.

Description of main conduit: Length 6 miles, diameter 12 inches.

Description of distributing reservoir: Capacity, 3,500,000 gallons; lined with clay; faced with brick on bottom and sides.

Sizes of distributing mains: 12 to 4 inches.

Available head: 55 pounds per square foot (average); water-supply sometimes deficient in very dry weather.

Total length of distributing mains: About 13 miles.

Number of water-takers: About 1,300.

Consumption of water: 450,000 gallons daily (estimated).

First cost of water-works: $200,000.

ARCHBALD:

Population: 3,049 inhabitants.

Name of corporation: Archbald Water Company (private).

Water obtained from: Laurel Run creek.

Total area of water-shed available: 4,000 acres.

Character and dimensions of dam: 300 feet long, 90 feet face (top), 20 feet deep; log cribbing filled with stone planked over, which is puddled clay.

Cost of dam: $15,000.

ARCHBALD—Continued.

Water first introduced: October, 1875.

Description of main conduit: 1,400 feet length, 10 inches diameter, terra cotta; 2,000 feet length, 10 and 8 inches diameter, iron reducer.

Description of distributing reservoir: Area, 90 feet face, 8 feet deep (average); in driest season supplied 60,000 gallons in 24 hours.

Sizes of distributing mains: 6, 4, and 3 inches.

Available head: 190 pounds per square inch (average).

Total length of distributing mains: 2 miles.

Number of water-takers: 80.

First cost of water-works: $14,000.

Number of fire-plugs: 9.

ASHLAND:

Population: 6,052 inhabitants.

Style of corporation: Municipal.

Water obtained from: Little Mahawnoy creek.

Total area of water-shed available: About 9 square miles.

Capacity of receiving reservoir: 3,000,000 gallons.

Character and dimensions of dam: 175 feet long, 19 feet high, 12 feet thick at base, tapered to 4 feet 6 inches on top; breast of rough stone, laid in cement and tamped with clay; built across valley.

Cost of dam: $4,200.

Water first introduced: April, 1877.

Description of main conduit: Length 27,800 feet, diameter 12 inches; cast iron.

Sizes of distributing mains: 8, 6, 4, and 3 inches.

Available head: 65 to 232 feet.

Total length of distributing mains: 14,000 feet.

Number of water-takers: 538.

Consumption of water: 150 gallons per head per day (estimated).

First cost of water-works: $62,300.

Average annual cost of maintenance and repairs: $750.

Number of fire plugs: 29.

CANTON:

Population: 1,194 inhabitants.

Name of corporation: Canton Water Company (private).

Water obtained from: Mountain stream.

Total area of water-shed available: 1½ square mile.

Water first introduced: October, 1877.

Description of main conduit: Diameters, 10, 6, 8, and 4 inches; cast iron.

Sizes of distributing mains: 6 and 4 inches.

Available head: 100 feet (average).

Total length of distributing mains: 1½ mile.

Number of water-takers: 100.

First cost of water-works: $37,500.

Average annual cost of maintenance and repairs: $350.

Number of fire-plugs: 2.

CARBONDALE:

Population: 7,714 inhabitants.

Name of corportion: Crystal Lake Water Company (private).

Water obtained from: Springs and streams.

Total area of water-shed available: About 2 square miles.

Capacity of receiving reservoirs: No. 1, 29,403,000 gallons; No. 2, 6,534,000 gallons.

Character and dimensions of dams: No. 1, earth embankment with wood bulkhead; No. 2, earth embankment with stone bulkhead.

Water first introduced: In 1867.

Description of main conduit: Length 4,847 feet, diameter 12 inches; iron and cement.

Description of distributing reservoir: Simply stone bulkhead.

Sizes of distributing mains: 10, 8, 6, and 4 inches.

Available head: 90 to 112 pounds per square inch.

Total length of distributing mains: About 3 miles.

Number of water-takers: 274.

First cost of water-works: $11,625.

Average annual cost of maintenance and repairs: About $400.

COATESVILLE:
Population: 2,766 inhabitants.
Name of corporation: Coatesville Water-Works (municipal).
Water obtained from: Springs.
Capacity of receiving reservoir: 2,000,000 gallons.
Character and dimensions of dam: Where stream is tapped, made of stone and earth; capacity, 600,000 gallons.
Cost of dam: $70,000.
Water first introduced: December, 1870.
Description of main conduit: Diameter, 10 inches; iron.
Description of distributing reservoir: Built of earth and puddled clay, with brick floor.
Sizes of distributing mains: 8, 6, 4, and 3 inches.
Available head: 100 feet (average).
Total length of distributing mains: About 5 miles.
Number of water-takers: 400.
Consumption of water: 200,000 gallons per day (estimated).
First cost of water-works: $65,000.
Average annual cost of maintenance and repairs: $250.
Number of fire-plugs: 57.

DOWNINGTON:
Population: 1,480 inhabitants.
Name of corporation: The Gas and Water Company of Downington (private).
Water obtained from: Springs.
Total area of water-shed available: 10 square miles.
Size of distributing mains: 6 inches.
Available head: 17 feet (average).
Total length of distributing mains: 7 miles.
Number of water-takers: 200.
Consumption of water: 200,000 gallons daily (estimated).
First cost of water-works: $50,000.
Number of fire-plugs: 1.

DUNMORE:
Population: 5,151 inhabitants.
Name of corporation: Dunmore Gas and Water Company (private).
Water obtained from: Little Roaning brook.
Total area of water-shed available: 1,500 acres.
Character and dimensions of dam: Stone and gravel.
Cost of dam: About $20,000.
Description of main conduit: Diameter, 12 inches; iron and cement.
Sizes of distributing mains: 12, 6, and 4 inches.
Available head: 100 to 150 feet.
Total length of distributing mains: 3 miles.
Number of water-takers: About 330.
First cost of water-works: $34,000.

EPHRATA:
Population: 392 inhabitants.
Name of corporation: Ephrata Water Company (private).
Water obtained from: Ephrata mountains.
Area and capacity of receiving reservoir: 7 acres; 63,000 gallons.
Cost of dam: $3,500.
Water first introduced: In December, 1878.
Description of main conduit: 3,700 feet long, 6 inches diameter; 300 feet long, 4 inches diameter; 600 feet long, 2 inches diameter; cast iron.
Description of distributing reservoir: Built of sandstone, lined with brick, inlaid with cement.
Sizes of distributing mains: 6 and 4 inches.
Available head: 265 feet (average).
Total length of distributing main: About 4,000 feet.
Number of water-takers: About 40.
Consumption of water: 1,000 gallons per day (estimated).
First cost of water-works: $3,500.
Average annual cost of maintenance and repair: $50.
Number of fire-plugs: 5.

FRANKLIN:
Population: 5,010 inhabitants.
Name of corporation: Venango Water Company (private).
Water obtained from: Springs.

FRANKLIN—Continued.
Total area of water-shed available: About 500 acres.
Receiving reservoirs: 2 small; temporary.
Cost of dam: $2,500 to $3,000.
Water first introduced: In 1864.
Sizes of distributing mains: 8 to 2 inches.
Available head: Water-supply deficient in dry seasons.
Total length of distributing mains: 50,000 feet.
Number of water-takers: About 630.
Consumption of water: 30 gallons per head daily (estimated).
First cost of water-works: $80,000.
Number of fire-plugs: 17.

GETTYSBURG:
Population: 2,814 inhabitants.
Name of corporation: Gettysburg Water Company (private).
Water obtained from: Springs.
Total area of water-shed available: About 150 acres.
Size of distributing mains: 3 inches.
Total length of distributing mains: About 2 miles.
Number of water-takers: 149.
Average annual cost of maintenance and repairs: $350.

HANOVER:
Population: 2,317 inhabitants.
Name of corporation: Hanover Water Company (private).
Water obtained from: Spring.
Capacity of receiving reservoirs: No. 1—2,500,000 gallons; No. 2—1,600,000 gallons.
Character and dimensions of dams: They are thrown up across a ravine.
Cost of dams: $5,725 94.
Water first introduced: January, 1874.
Description of main conduit: Length 17,931 feet, diameter 6 inches; cast iron.
Discharging capacity: 350,000 gallons in 24 hours; head, 206 feet (average).
Size of distributing mains: 4 inches.
Available head: 190 feet (average).
Total length of distributing mains: About 13,100 feet.
Number of water-takers: 213.
Consumption of water: 30,000 to 40,000 gallons per day (estimated.
First cost of water-works: $37,000.
Average annual cost of maintenance and repairs: $300.
Number of fire-plugs: 25.

HAZLETON:
Population: 6,935 inhabitants.
Name of corporation: Hazleton Water Company (private).
Water obtained from: Springs and artesian wells.
Capacity of receiving reservoirs: 5 reservoirs; capacity, 690,156 cubic feet.
Water first introduced: In 1860.
Description of main conduit: Length 3,205 feet, diameter 8 inches; cast iron.
Sizes of distributing mains: 6 inches.
Available head: Water-supply sometimes deficient.
Total length of distributing mains: 4½ miles.
Average annual cost of maintenance and repairs: $3,500.
Number of fire-plugs: 17.

HOLLIDAYSBURG:
Population: 3,150 inhabitants.
Name of corporation: Hollidaysburg Water-Works (municipal).
Water obtained from: Roaring run.
Total area of water-shed available: 560 acres.
Area and capacity of receiving reservoir: 528 acres; 928,000 cubic feet.
Cost of dam: $17,258.
Water first introduced: November, 1867.
Description of main conduit: Length 11⅜ miles, diameters 6, 5, 4, and 3 inches; wood.
Sizes of distributing mains: 6, 5, 4, and 3 inches.

HOLLIDAYSBURG—Continued.

Available head: 28 to 120 feet; water-supply deficient only in dry months.
Total length of distributing mains: 8⅓ miles.
Number of water-takers: 763.
First cost of water-works: $47,600.
Average annual cost of maintenance and repairs: About $1,200.
Number of fire-plugs: 47.

JOHNSTOWN:

Population: 8,380 inhabitants.
Name of corporation: Johnstown Water Company (private).
Water obtained from: Mountain streams, Mill run, Laurel run, Wild Cat, and Conemaugh.
Total area of water-shed available: 191 square miles.
Capacity of receiving reservoir: 36,000,000 gallons.
Character and dimensions of dams: No. 1—550 feet long, 16 feet deep. No. 2—300 feet long, 20 feet wide; the two made in valleys with an overflow for surplus; overflow 50 feet wide. No. 3—150 feet long, 6 feet high; timber frame with overflow.
Cost of dams: No. 1, $22,235; No. 2, $9,000; No. 3, $3,900.
Water first introduced: July, 1868.
Description of main conduit: No. 1, length 3 miles, diameter 12 inches; No. 2, length 4¼ miles, diameter 16 inches; No. 3, length 5 miles, diameter 20 inches; cast iron.
Sizes of distributing mains: 20, 16, 12, 6, and 4 inches.
Available head: 50 to 60 pounds; 178 feet (average).
Total length of distributing mains: 30 miles.
Number of water-takers: 2,000.
First cost of water-works: $375,000.
Average annual cost of maintenance and repairs: $3,000.
Number of fire-plugs: 54.

LEBANON:

Population: 8,778 inhabitants.
Name of corporation: Lebanon Borough Water-Supply Company (municipal).
Water obtained from: Cornwall hills.
Total area of water-shed available: 1,111.7 acres.
Capacity of receiving reservoir: 3,000,000 gallons per day.
Character and capacity of dam: Across valley; capacity, 20,000,000 gallons.
Cost of dam: $300,000.
Water first introduced: In 1872.
Description of main conduit: Length 3½ miles, 16 inches diameter; length 2½ miles, 12 inches diameter; iron.
Discharging capacity: 1,000,000 gallons per day; head, 152 feet (average).
Sizes of distributing mains: 12, 8, and 6 inches.
Available head: 100 feet (average); water-supply sometimes deficient.
Total length of distributing mains: About 16 miles.
Number of water-takers: 930.
Consumption of water: 270,000 gallons per day; 30 gallons per head (estimated).
First cost of water-works: About $280,000.
Average annual cost of maintenance and repairs: $1,000.
Number of fire-plugs: 70.

MAHANOY CITY:

Population: 7,181 inhabitants.
Name of corporation: Mahanoy City Water Company (private).
Water obtained from: Springs and streams.
Total area of water-shed available: About 2,000 acres.
Character and dimensions of dams: 2 dams; cover about 20 acres; breast 22 feet high, made of earth.
Cost of dams: $77,500.
Water first introduced: In 1867.
Description of main conduit: 2 miles long, 10 inches diameter; ½ mile long, 6 inches diameter; 1 mile long, 4 inches diameter; cast iron.
Size of distributing mains: 10 inches.
Available head: 350 feet (average).
Total length of distributing mains: 3½ miles.

MAHANOY CITY—Continued.

Number of water-takers: 734.
First cost of water-works: $45,000.
Average annual cost of maintenance and repairs: About $2,000.
Number of fire-plugs: 17.

MECHANICSBURG:

Population: 3,018 inhabitants.
Name of corporation: Mechanicsburg Gas and Water Company (private).
Water obtained from: Springs.
Total area of water-shed available: About 1 square mile.
Capacity of receiving reservoir: About 1,000,000 gallons.
Character and dimensions of dams: Water passes from No. 1 through tunnel to No. 2; tunnel 700 feet long, 6 by 3 feet, with many springs in it.
Cost of dams: $1,500.
Water first introduced: In 1856 or 1857.
Description of main conduit: Length 2 miles, diameter 6 inches; cast iron.
Description of distributing reservoir: Size, 90 by 60 feet; 14 feet deep; built in ravine; breast made of excavated earth, lined with red sandstone; dams are similar, and partly lined with boards.
Sizes of distributing mains: 6, 4, 3, and 2 inches.
Available head: 25 feet (average); water-supply sometimes deficient.
Total length of distributing mains: About 2 miles.
Number of water-takers: About 500.
First cost of water-works: $25,000.
Average annual cost of maintenance and repairs: About $100.
Filtering apparatus: When water leaves receiving dam it runs through one copper and five galvanized iron strainers in a wooden trough; cleaned about once in six or eight weeks.
Number of fire-plugs: 21.

MINERSVILLE:

Population: 3,249 inhabitants.
Name of corporation: Minersville Water Company (private).
Water obtained from: Springs.
Total area of water-shed available: 25 square miles.
Cost of dam: $1,000.
Water first introduced: In 1860.
Description of main conduit: 4 miles long, 8 inches diameter; cast iron.
Sizes of distributing mains: 8 to 3 inches.
Available head: About 120 feet (average).
Total length of distributing mains: 7½ miles.
Number of water-takers: About 625.
First cost of water-works: About $53,000.
Average annual cost of maintenance and repairs: $900.
Number of fire-plugs: 40.

PLYMOUTH:

Population: 6,065 inhabitants.
Name of corporation: The Plymouth Water Company (private).
Water obtained from: Springs.
Total area of water-shed available: 5 square miles.
Capacity of receiving reservoirs: One water-shed, four reservoirs; 10,000,000 gallons.
Character and dimensions of dams: No. 1—80 feet long, 15 feet deep; cut stone, cemented. No. 2—110 feet long, 20 feet deep; cut stone, cemented. No. 3—130 feet long, 25 feet deep; stone sheet, piled and puddled. No. 4—330 feet long, 12 feet deep; stone sheet, piled and puddled.
Cost of dams: No. 1, $2,500; No. 2, $7,500; No. 3, $4,500; No. 4, $4,000.
Water first introduced: In 1876.
Description of main conduit: Length 1,200 feet, diameter 12 inches; cast iron.
Discharging capacity: About 750 cubic feet per minute; head, 165 feet (average).
Description of distributing reservoir: A dam built of stone, cemented; 80 feet long, 15 feet high; capacity, 175,000 gallons.

PLYMOUTH—Continued.
Sizes of distributing mains: 10, 8, 6, 3, and 2 inches.
Available head: 250 feet (average).
Total length of distributing mains: 30,000 feet.
Number of water-takers: 840.
Consumption of water: 175,000 gallons daily (estimated).
First cost of water-works: $55,000.
Average annual cost of maintenance and repairs: $1,200.
Filtering system: Pipes cleaned once a year.
Number of fire-plugs: 1.

POTTSVILLE:
Population: 13,253 inhabitants.
Name of corporation: The Pottsville Water Company (private).
Water obtained from: Streams.
Area and capacity of receiving reservoir: 70 acres; 300,000,000 gallons.
Character and dimensions of dam: 1,350 feet long, 42 feet high, 40 feet wide on top; slope 2 to 1 inside, 1½ to 1 outside; earth wasteway 40 feet wide, 4 feet deep.
Cost of dam: $90,000.
Water first introduced: In 1855.
Description of main conduits: 7 miles long, 12 inches diameter; 4 miles long, 12 inches diameter; cast-iron.
Sizes of distributing mains: 12 to 3 inches.
Available head: 20 to 80 pounds.
Total length of distributing mains: 24 miles.
Number of water-takers: 3,150.
First cost of water-works: $300,000.
Average annual cost of maintenance and repairs: $3,000.

READING:
Population: 43,278 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs.
Total area of water-shed available: 20 square miles.
Area and capacity of receiving reservoir: 27 acres; 115,000,000 gallons.
Cost of dams: $240,000.
Water first introduced: In 1865.
Description of main conduit: Length, 4 miles; diameters, 24 and 10 inches; cast iron.
Description of distributing reservoir: Area, 1 acre; 15 feet deep.
Capacity: 6,000,000 gallons.
Sizes of distributing mains: 24 to 4 inches.
Available head: 45 pounds (average).
Total length of distributing mains: 35 miles.
Number of water-takers: 9,000.
Consumption of water: 3,000,000 gallons daily; 50 gallons per head (estimated).
First cost of water-works: $300,000.
Average cost of maintenance and repairs: $5,200.
Number of fire-plugs: 375.

RENOVO:
Population: 3,708 inhabitants.
Name of corporation: Renovo Water-Works (municipal).
Water obtained from: Mountain stream.
Capacity of receiving reservoir: 4,000,000 gallons.
Cost of dam: $9,000.
Water first introduced: In 1873.
Size of distributing mains: 10 inches.
Available head: Water-supply sometimes deficient.
Total length of distributing mains: 5 or 6 miles.
Number of water-takers: 250.
First cost of water-works: $60,000.
Average annual cost of maintenance and repairs: $200.
Number of fire-plugs: 19.

SCRANTON:
Population: 45,850 inhabitants.
Name of corporation: Scranton Gas and Water Company (private).
Water obtained from: Mountain lake and stream.
Total area of water-shed available: 30 square miles.

SCRANTON—Continued.
Capacity of receiving reservoirs: Lake, 400,000,000 gallons; reservoir, 90,000,000 gallons.
Character and dimensions of dams: 320 feet long, 22 feet wide bottom, 8 feet wide on top; 37 feet high above natural bed of creek; solid masonry.
Cost of dams: $90,000.
Water first introduced: In 1860.
Description of main conduits: 1,600 feet long, 16 inches diameter; and 1,600 feet long, 16 inches diameter; cast and wrought iron and cement.
Discharging capacity: 12,000,000 gallons in 24 hours; head, 50 to 400 feet.
Description of distributing reservoir: Area, 25 acres; capacity, 90,000,000 gallons; rocky bottom.
Sizes of distributing mains: 16 to 14 inches.
Available head: 50 pounds (average).
Total length of distributing mains: 27½ miles.
Number of water-takers: 2,100.
Consumption of water: 5,000,000 gallons per day.
First cost of water-works: $640,000.
Average annual cost of maintenance and repairs: $8,000.
Number of fire-plugs: 115.

SEWICKLEY:
Population: 2,053 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs.
Total area of water-shed available: About 100 acres.
Character and dimensions of dam: 12 feet wide; flood-gate in center, to allow impure water to run off during heavy rains.
Cost of dam: $75,000.
Water first introduced: In 1874.
Description of main conduit: 75 feet long, 12 inches diameter; cast iron.
Description of distributing reservoir: 300 feet long, 200 feet wide, 19 feet deep; 3 outlets on stand-pipe; water drawn from bottom; capacity, 4,000,000 gallons.
Sizes of distributing mains: 12, 8, 6, and 4 inches.
Available head: 50 pounds (average).
Total length of distributing mains: About 10 miles.
Number of water-takers: 350.
Consumption of water: 10,650,000 gallons per day (estimated).
First cost of water-works: $75,000.
Average annual cost of maintenance and repairs: $600.
Number of fire-plugs: 4.

SLATINGTON:
Population: 1,634 inhabitants.
Name of corporation: Slatington Water Company (private).
Water obtained from: Springs.
Water first introduced: In 1862.
Description of main conduit: Length 1½ mile, diameter 4 inches; iron.
Sizes of distributing mains: 4 and 3 inches.
Available head: 100 to 150 feet; water-supply deficient in long dry spells in summer.
Number of water-takers: 150.
Consumption of water: 50 gallons per head daily.
First cost of water-works: $8,000.
Average annual cost of maintenance and repairs: $100 to $200.

STROUDSBURG:
Population: 1,860 inhabitants.
Name of corporation: Stroudsburg Water Company (private).
Water obtained from: Springs.
Water first introduced: October, 1876.
Description of main conduit: Diameter, 6 inches.
Discharging capacity: 1,000 gallons per minute.
Description of distributing reservoir: Capacity, 1,000,000 gallons.
Sizes of distributing mains: 6, 4, 3, and 2 inches.
Available head: 135 feet (average); water-supply is deficient; dam is too small.
Total length of distributing mains: 1 mile.

STROUDSBURG—Continued.
Number of water-takers: 100.
Average cost of maintenance and repairs: $20 75.
Number of fire-plugs: 15.

SUSQUEHANNA:
Population: 3,467 inhabitants.
Name of corporation: Susquehanna Water Company (private).
Water obtained from: Springs.
Cost of dam: $300.
Water first introduced: In 1876.
Description of main conduit: ½ mile long, 6 inches diameter; cast iron.
Size of distributing mains: 6 inches.
Available head: 99 feet (average).
Total length of distributing mains: ½ mile.
Number of water-takers: 64.
First cost of water-works: $5,000.
Average annual cost of maintenance and repairs: Nothing.

TIDIOUTE:
Population: 1,255 inhabitants.
Name of corporation: Tidioute Water Company (private).
Water obtained from: Springs and brooks.
Total area of water-shed available: About 12 square miles.
Capacity of receiving reservoir: 39,200 cubic feet.
Water first introduced: In 1871.
Description of main conduit: Length 3½ miles, diameter 4 inches; cast iron.
Description of distributing reservoir: Capacity, 39,200 cubic feet; constructed of stone on bed of cement.
Sizes of distributing mains: 8 and 4 inches.
Available head: 60 pounds (average).
Total length of distributing mains: 2½ miles.
Number of water-takers: 90.
Consumption of water: 150 gallons per day per head (estimated).
First cost of water-works: $26,000.
Average annual cost of maintenance and repairs: $850.
Number of fire-plugs: 13.

TOWANDA:
Population: 3,814 inhabitants.
Name of corporation: Towanda Water-Works (private).
Water obtained from: Springs.
Total area of water-shed available: 5 square miles.
Capacity of receiving reservoir: 750,000 gallons.
Water first introduced: In 1880.
Description of main conduit: Cast iron.
Description of distributing reservoir: Earth bank.
Sizes of distributing mains: 12 to 6 inches.
Available head: 20 to 225 feet.
Total length of distributing mains: About 9 miles.
Filtering system: Sand, gravel, and charcoal; cleaned twice a year.
Number of fire-plugs: 50.

TREMONT:
Population: 1,785 inhabitants.
Name of corporation: The Tremont Water and Gas Company (private).
Water obtained from: Springs and ravines.
Total area of water-shed available: About 6 square miles.
Capacity of receiving reservoirs: 1st, 3,000 gallons; 2d, 18,000 gallons; 3d, 60,000 gallons; 4th, 600,000 gallons; one built in ravine, 3 excavated.
Cost of dam: $1,600.
Water first introduced: In 1867.
Description of main conduit: Diameters, 6, 4, and 3 inches; cast iron.
Discharging capacity: 100 gallons per minute.
Sizes of distributing mains: 6, 4, and 3 inches.
Available head: 75 feet (average).
Total length of distributing mains: About 12,000 feet.
Number of water-takers: 30.
Consumption of water: 15,000 gallons per day (estimated).

TREMONT—Continued.
First cost of water-works: About $20,000.
Average annual cost of maintenance and repairs: About $40.
Number of fire-plugs: 3.

TUNKHANNOCK:
Population: 1,116 inhabitants.
Name of corporation: The Tunkhannock Water Company (private).
Water obtained from: Springs.
Total area of water-shed available: About 200 acres.
Character of dam: The water from five springs in a ravine is impounded by a dam immediately below each spring, making a series of reservoirs at different altitudes.
Cost of dam: About $150.
Water first introduced: In 1870.
Description of main conduit: Length 675 feet, diameter 8 inches; length 4,050 feet, diameters 4 and 3 inches; cast iron.
Size of distributing mains: 3 inches.
Available head: 125 to 150 feet.
Total length of distributing mains: 4¾ miles.
Number of water-takers: 200.
Consumption of water: 5 gallons per head per day (estimated).
First cost of water-works: About $12,000.
Average annual cost of maintenance and repairs: About $150.
Number of fire-plugs: 10.

WILKESBARRE:
Population: 23,339 inhabitants.
Name of corporation: Crystal Springs Water Company (private).
Water obtained from: Running streams.
Total area of water-shed available: About 40,000 acres.
Area and capacity of receiving reservoir: 1,100 acres; depth, 5 feet (average).
Cost of dam: $162,757 66.
Water first introduced: In 1871.
Description of main conduit: 7,632 feet long, 10 inches diameter; 11,494 feet long, 8 inches diameter; 20,038 feet long, 6 inches diameter; 6,040 feet long, 4 inches diameter—cement; 5,652 feet long, 12 inches diameter; 6,408 feet long, 10 inches diameter; 3,000 feet long, 8 inches diameter; 11,200 feet long, 4 inches diameter—iron coated with coal-tar.
Description of distributing reservoir: Area, 11 acres; on very high ground; can supply consumers for 6 months; water runs through rocky bed.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 260 feet (average).
Number of water-takers: 1,100.
First cost of water-works: $80,000.
Average annual cost of maintenance and repairs: $800.
Number of fire-plugs: 60.

WILLIAMSPORT (1):
Population: 18,934 inhabitants.
Name of corporation: The Citizen and Gas Company of Williamsport (private).
Water obtained from: Mountain streams.
Total area of water-shed available: About 25 square miles.
Area and capacity of receiving reservoir: 70 by 70 by 8 feet.
Water first introduced: In 1867.
Description of main conduit: 3 miles long, 10 inches diameter; cast iron, coated.
Sizes of distributing mains: 12, 8, 6, 4, and 3 inches.
Available head: About 40 pounds (average).
Total length of distributing mains: About 7 miles.
Number of water-takers: About 800.
First cost of water-works: About $250,000.
Number of fire-plugs: 50.

WILLIAMSPORT (2):
Population: 18,934 inhabitants.
Name of corporation: Williamsport Water Company (private).
Water obtained from: Mountain springs.
Total area of water-shed available: About 5 square miles.
Capacity of receiving reservoir: 15,000,000 gallons.

WILLIAMSPORT (2)—Continued.
Character of dam: 20 feet high.
Water first introduced: In 1856.
Description of main conduit: Diameters, 16 and 8 inches.
Sizes of distributing mains: 10 to 4 inches.
Available head: 46 pounds (average).
Total length of distributing mains: 20 miles.
Number of water-takers: 1,838.
First cost of water-works: $173,000.
Average annual cost of maintenance and repairs: $3,500.
Number of fire-plugs: 120.

RHODE ISLAND.

WESTERLY:
Population: 6,104 inhabitants.
Style of corporation: Private.
Water obtained from: Springs.
Water first introduced: In 1876.
Description of distributing reservoir: Size, 12 by 30 feet by 9½ feet deep; built on hillside; fed by springs.
Sizes of distributing mains: 4 and 3 inches.
Available head: 30 to 40 feet.
Total length of distributing mains: 5,000 feet.

UTAH.

LOGAN:
Population: 3,396 inhabitants.
Name of corporation: Logan City Water-Works (municipal).
Water obtained from: Logan river.
Total area of water-shed available: 130,000 acres.
Capacity of receiving reservoir: 130 gallons for one district.
Character and dimensions of dam: Water-supply comes into reservoir through L. and R. Canal Company, which dam is ¾ mile from reservoir.
Cost of dam: $13,000.
Water first introduced: September, 1879.
Description of distributing reservoir: Size 65 feet by 25 feet, 14 feet deep; built of rock laid in cement; 6 large and 2 small compartments. This reservoir is also the settler; water passes through screens, drains at bottom and cleans out sediment.
Size of distributing mains: 6 inches.
Available head: 100 to 150 feet.
Total length of distributing mains: About 2 miles.
Number of water-takers: 15.
Consumption of water: 50 gallons per head daily (estimated).
First cost of water-works: About $13,000.
Filtering system: Only screens in reservoir.
Number of fire-plugs: 11.

SALT LAKE CITY:
Population: 20,768 inhabitants.
Name of corporation: Salt Lake City Water-Works (municipal).
Water obtained from: City creek.
Capacity of receiving reservoirs: 3 small ones; total capacity, 103,350 gallons.
Character and dimensions of dam: One small one of wood and rock, near the head of flume supplying reservoirs.
Cost of dam: $10,000.
Water first introduced: In 1873.
Description of main conduit: 269 feet long; 4 feet wide, and 3 feet high; California redwood.
Discharging capacity: 24,000,000 gallons per day; head 3 feet (average).
Description of distributing reservoir: Ordinary tank, 28 by 16 feet; 10 feet deep; three compartments for cleaning and repairing.
Sizes of distributing mains: 20, 18, 10, 6, and 4 inches.
Available head: 70.01 pounds (average).
Total length of distributing mains: 10½ miles.
Number of water-takers: 700.
Consumption of water: 200,000 gallons per day (estimated).
First cost of water-works: About $100,000.

SALT LAKE CITY—Continued.
Average annual cost of maintenance and repairs: Between $2,000 and $3,000.
Filtering system: Ordinary screens, cleaned once a week.
Number of fire-plugs: 116.

VERMONT.

BELLOWS FALLS:
Population: 2,229 inhabitants.
Style of corporation: Municipal.
Water obtained from: Pond.
Total area of water-shed available: ½ square mile.
Character and dimensions of dam: 225 feet long, 3 feet high; earth; trenching and planking across outlet, and filling sides with heavy gravity rails 12 feet wide.
Cost of dam: $1,000.
Water first introduced: In 1849.
Description of main conduit: 9,440 feet long, 8 inches diameter; cast iron.
Sizes of distributing mains: 7 and 6 inches.
Available head: 280 feet (average).
Total length of distributing mains: 5.56 miles.
Number of water-takers: 290.
Consumption of water: 84,000 gallons per day (estimated).
First cost of water-works: $10,000.
Average annual cost of maintenance and repairs: $400.
Number of fire-plugs: 33.

BRANDON:
Population: 3,280 inhabitants.
Style of corporation: Municipal.
Water obtained from: Hitchcock pond.
Total area of water-shed available: 1 mile by ½ mile.
Cost of dam: $500.
Water first introduced: January, 1879.
Description of main conduit: 7,000 feet long, 12 inches diameter; 23,465 feet long, 8 inches diameter; 7,853 feet long, 6 inches diameter; 7,938 feet long, 4 inches diameter; cast iron, coated with coal-tar inside and outside.
Description of distributing reservoir: A lake 1 mile long, ½ mile wide; pipe enters 10 feet below surface; stone-paved (by nature) with cobble-stones; supplied entirely by springs.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 150 to 175 feet.
Total length of distributing mains: 3½ miles.
Number of water-takers: 125.
First cost of water-works: About $40,000.
Average annual cost of maintenance and repairs: About $50.

FAIR HAVEN:
Population: 2,211 inhabitants.
Name of corporation: Fair Haven Water-Works (municipal).
Water obtained from: Inman pond.
Area of receiving reservoir: Pond, ½ mile long, ¼ mile wide; banks of stone, 10 feet above water-line; overflow at one end 10 feet wide.
Cost of dam: $10.
Water first introduced: December, 1880.
Sizes of distributing mains: 6, 4, and 2 inches.
Available head: 80 to 100 pounds.
Total length of distributing mains: About 4 miles.
Number of water-takers: 65.
First cost of water-works: $36,000 or $37,000.
Number of fire-plugs: 26.

SAINT ALBANS:
Population: 7,193 inhabitants.
Name of corporation: Saint Albans Water-Works (municipal).
Water obtained from: Small streams.
Total area of water-shed available: 2,000 acres.
Character and dimensions of dam: 400 feet long, from 1 to 25 feet high; embankment, 2,150 feet long.
Cost of dam: $160,000.
Water first introduced: In 1872.

SAINT ALBANS—Continued.

Description of main conduit: 3½ miles long, 12 inches diameter; wrought iron, cement-lined.
Description of distributing reservoir: Receiving and distributing reservoirs are the same.
Sizes of distributing mains: 12 to 3 inches.
Available head: 60 to 150 feet.
Total length of distributing mains: 13 miles.
Number of water-takers: 550.
Consumption of water: 30 gallons per head daily (estimated).
First cost of water-works: $150,000.
Average annual cost of maintenance and repairs: $1,500.
Number of fire-plugs: 54.

VIRGINIA.

UNIVERSITY OF VIRGINIA:

Name of corporation: University of Virginia (state).
Water obtained from: Reservoir.
Area and capacity of receiving reservoir: About 12,000,000 gallons.
Character and dimensions of dams: 100 feet long at top, 40 feet long at bottom, 15 feet high; brick, laid in cement, built across ravine.
Cost of dam: $2,218 12.
Water first introduced: In 1869.
Description of main conduit: 2 miles long, 4 inches diameter; cast iron.
Discharging capacity: 60 gallons per minute; head, 70 feet (average).
Sizes of distributing mains: 3 and 2 inches.
Available head: 70 feet (average); water-supply sometimes deficient.
Total length of distributing mains: About 1½ mile.
Number of water-takers: 18.
Consumption of water: 20 gallons per head per day (estimated).
First cost of water-works: $22,380.
Filtering apparatus: Strainer, surrounded by brick structure 3 feet square, 10 feet high; well is double, space filled with charcoal; cleaned once in ten years.
Number of fire-plugs: 6.

WINCHESTER:

Population: 4,958 inhabitants.
Style of corporation: Municipal.
Water obtained from: Limestone spring.
Water first introduced: In 1864.
Size of distributing mains: 6 inches.
Available head: 42 feet (average).
Total length of distributing mains: 20 miles.
First cost of water-works: $14,000.
Average annual cost of maintenance and repairs: $800 to $1,000.
Number of fire-plugs: 24.

WASHINGTON TERRITORY.

WALLA-WALLA:

Population: 3,588 inhabitants.
Name of corporation: Walla-Walla Water Company (private).
Water obtained from: Springs.
Cost of dam: $5,000.
Water first introduced: In 1868.
Description of distributing reservoir: 125 by 75 feet; 9 feet deep.

WALLA-WALLA—Continued.

Sizes of distributing mains: 10 to 4 inches.
Available head: 20 pounds (average).
Total length of distributing mains: 23,000 feet.
Number of water-takers: 175.
First cost of water-works: $10,000.

WISCONSIN.

FOND DU LAC:

Population: 13,094 inhabitants.
Style of corporation: Private.
Water obtained from: Flowing fountain.
Water first introduced: In 1840.
First cost of water-works: From $100 to $1,500.

KENOSHA (1):

Population: 5,039 inhabitants.
Name of corporation: North Side Water Company (private).
Water obtained from: Artesian wells.
Water first introduced: December, 1880.
Description of main conduit: Length 1½ mile, diameters 6 and 4 inches.
Discharging capacity: 7,000 gallons per minute; head, 55 pounds (average).
Size of distributing mains: 6 and 4 inches.
Available head: 30 pounds (average).
Total length of distributing mains: 1½ mile.
Number of water-takers: 28.
Consumption of water: 50,000 gallons per day (estimated).
First cost of water-works: $8,000.
Average annual cost of maintenance and repairs: About $800.
Number of fire-plugs: 9.

KENOSHA (2):

Population: 5,039 inhabitants.
Name of corporation: Park City Water Company (private).
Water obtained from: Artesian wells.
Area and capacity of receiving reservoir: Well, 1,368 feet deep, 6 inches bore; 1,500 gallons per minute.
Water first introduced: June, 1880.
Sizes of distributing mains: 6 and 4 inches.
Available head: 100 feet (average).
Total length of distributing mains: 5 miles.
Number of water-takers: 230.
First cost of water-works: $17,000.
Average annual cost of maintenance and repairs: About $1,200.
Number of fire-plugs: 22.

PRAIRIE DU CHIEN:

Population: 2,777 inhabitants.
Name of corporation: Prairie du Chien Artesian Well Company (private).
Water obtained from: Artesian wells.
Capacity of receiving reservoir: 640 gallons per minute.
Cost of dam: $3,000.
Water first introduced: In 1876.
Size of distributing mains: 6 inches.
Available head: 20 to 40 feet; water-supply sometimes deficient.
Total length of distributing mains: 1,500 feet.
Number of water-takers: 24.
First cost of water-works: $4,500.
Average annual cost of maintenance and repairs: $50.
Number of fire-plugs: 7.

WATER-WORKS EMPLOYING SYSTEM OF PUMPING TO DISTRIBUTING RESERVOIRS.

CALIFORNIA.

MARYSVILLE:

Population: 4,321 inhabitants.
Name of corporation: Marysville Water Company (private).
Water obtained from: Two artesian wells. Well No. 1, 80 feet deep, 12-inch bore; well No. 2, 150 feet deep, 12 inch bore.
Water first introduced: September, 1859.
Sizes of distributing mains: 12 to 2 inches.
Total length of distributing mains: 8 miles.
Number of water-takers: 700.
Consumption of water: 800,000 gallons per day in summer, 300,000 gallons per day in winter (estimated).
First cost of water-works: $200,000.
Average annual cost of maintenance and repairs: $1,800.
Number of fire-plugs: 12.
Design and dimensions of pumps and water-plungers: 1 Laswell, Marysville, pump, plunger 7 inches diameter, 35 strokes per minute; 1 Worthington No. 4 New York pump, plunger 14 inches diameter, 60 strokes per minute.
Time pumps are run: 5 to 12 hours per day.
Description of force-main: Head on pumps, 52 feet.
Description of water-valves: Solid rubber.
Kind of power used: Steam.
Description of boilers: 54 inches diameter, 16 feet long; fuel, wood.
Description of engine: Condensing low-pressure; 10 inches diameter, 14 inches stroke; globe valves.
Cost of engine and pumps: $8,000.

SAN DIEGO:

Population: 2,637 inhabitants.
Name of corporation: San Diego Water Company (private).
Water obtained from: San Diego river.
Water first introduced: In 1873.
Description of reservoirs: Settling reservoir, capacity, 80,000 gallons; storage reservoir, capacity, 800,000 gallons; distributing reservoir, capacity, 44,000 gallons; all walled with rock and cement.
Size of distributing mains: 5 inches.
Available head: 200 feet (average).
Total length of distributing mains: 8 miles.
Number of water-takers: 225.
Consumption of water: 85,000 gallons per day in summer, 40,000 gallons per day in winter (estimated).
First cost of water-works: $76,937 62.
Average annual cost of maintenance and repairs: $5,000.
Number of fire-plugs: 4.
Design and dimensions of pump and water-plunger: Hooker pump, by Garretts & Co., San Francisco, California; plain plunger, 36 inches stroke, 8 inches diameter, 28 strokes per minute.
Time pump is run: 11 hours per day.
Description of force-main: ½ mile long; 220 feet head on pumps.
Description of water-valves: Vulcanized spring, 8- and 4-inch.
Kind of power used: Steam.

SAN DIEGO—Continued.

Description of boilers: Tubular, 4 by 15 feet; 40 tubes; 40 pounds pressure; fuel, wood.
Description of engine: Simple, 14 inches diameter, 28 inches stroke; 42 single strokes per minute; slide-valves.
Cost of engine: $3,000.
Duty of engine: 1,315,000 pounds daily.

COLORADO.

CAÑON CITY.

Population: 1,501 inhabitants.
Name of corporation: Cañon City Water Company (private).
Water obtained from: Arkansas river.
Capacity of receiving reservoir: 1,000,000 gallons.
Cost of dam: $3,500.
Water first introduced: January, 1881.
Description of distributing reservoir: Capacity, 1,000,000 gallons; on an elevation of 140 feet above town.
Sizes of distributing mains: 10, 8, and 6 inches.
Available head: 140 feet (average).
Total length of distributing mains: Over 3 miles.
Number of water-takers: 120.
First cost of water-works: $45,000.
Filtering system: Well, 30 by 100 feet, 12 feet deep; natural gravel formation.
Number of fire-plugs: 15.
Design of pump: Knowles pump, Boston, August, 1880; 30 strokes per minute.
Time pump is run: 4 hours per day.
Kind of power used: Water.
Character and dimensions of water-wheels: Two 48-inch turbine, Whitney's, Leominster, Massachusetts; 11 feet head.

TRINIDAD:

Population: 2,226 inhabitants.
Name of corporation: The Trinidad Water-Works Company (private).
Water obtained from: Well.
Cost of dam: $8,000.
Water first introduced: October, 1879.
Description of main conduit: 300 feet long, 2 feet wide, 3 feet high; laid in stone and covered with cap-stones.
Discharging capacity: 2,000,000 gallons per 24 hours, under 6 feet head.
Description of distributing reservoir: Rectangular; 150 by 250 feet, 16 feet deep; bottom paved with round stones and grouted with cement and concrete; sides paved with flat stones in regular courses 8 inches thick; joints filled with cement.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 120 feet (average).
Total length of distributing mains: 26,800 feet.
Number of water-takers: 250.
Consumption of water: 90,000 gallons per day (exactly).
First cost of water-works: $70,000.
Average annual cost of maintenance and repairs: $1,500.
Number of fire-plugs: 30.

TRINIDAD—Continued.

Design and dimensions of pump and water-plungers: Pump made by Cope and Maxwell Manufacturing Company, Hamilton, Ohio; two plain plungers, 30 inches stroke, 10 inches diameter, 40 strokes per minute; pump-barrel, 11 inches diameter.

Time pump is run: 10 hours per day.

Description of force-main: Length 5,500 feet, diameter 12 inches; head, 310 feet on pump.

Description of water-valves: Rubber; 8 inches diameter, 1 inch lift.

Kind of power used: Steam.

Description of boilers: Steel; 24 by 4 feet; four 8- and two 10-inch flues; fuel, gas or coking-coal.

Description of engine: Compound non-condensing; 16 inches diameter, 22 inches stroke, 40 strokes per minute; slide-valves.

Cost of engine: $8,000.

DELAWARE.

NEW CASTLE:

Population: 3,700 inhabitants.

Name of corporation: New Castle Water-Works (private).

Character and dimensions of dam: 200 feet long, 8 feet high; made of stone and earth.

Water first introduced: In 1870.

Description of main conduit: 4 miles long, 10 inches diameter; cast iron.

Capacity of distributing reservoir: 1,000,000 gallons.

Sizes of distributing mains: 10, 8, 6, and 4 inches.

Available head: About 40 pounds (average).

Total length of distributing mains: About 6 miles.

Number of water-takers: About 300.

Consumption of water: 100 gallons per capita daily (estimated).

First cost of water-works: About $100,000.

Average annual cost of maintenance and repairs: About $500.

Number of fire-plugs: 35.

Design of pump: Blake pump, 25 strokes per minute.

Time pump is run: 80 hours per week.

Time spent in repairs: About 40 hours per year.

Description of force-main: 1½ mile long; 40 pounds head on pump.

Description of water-valves: Made of gum.

Kind of power used: Steam.

Description of engine: Non-condensing; 25 strokes per minute.

Cost of engine: About $4,000.

Remarks: Water has some sediment, but pronounced by chemists not to be detrimental to health.

WILMINGTON:

Population: 42,478 inhabitants.

Name of corporation: Wilmington Water-Works (municipal).

Water obtained from: Brandywine before it reaches tide-water.

Water first introduced: November, 1827.

Description of distributing reservoirs: Low-service, capacity 3,500,000 gallons; high-service, capacity 2,000,000 gallons.

Sizes of distributing mains: 30, 20, 16, 12, 10, 8, 6, and 4 inches.

Available head: 140 to 240 feet.

Total length of distributing mains: 272,694 feet.

Number of water-takers: 4,344.

Consumption of water: 81 gallons per head daily.

First cost of water-works: $874,566 60.

Average annual cost of maintenance and repairs: $25,193 36.

Number of fire-plugs: 470.

Design and dimensions of pumps and plungers: Worthington 1872 pump, 12 strokes per minute; Knowles 1880 pump, 50 strokes per minute; Jonval turbine bucket-plunger, 11½ inches diameter.

Time spent in repairs: 100 hours per year.

Description of force-main: 1,600 feet long, 30 inches diameter; 57 pounds pressure; Knowles pump, 55 pounds pressure; 12-inch main.

WILMINGTON—Continued.

Kind of power used: Steam and water.

Character and dimensions of water-wheel: One Geyelin-Jonval turbine, 14 feet head and fall, 18 revolutions per minute; 3 gallons of water used to lift 1 to reservoir.

Fuel used: Cumberland coal used for fuel, from George's creek.

Description of engines: Worthington duplex, 11 strokes per minute; Knowles' simple.

Cost of engines: Worthington, $37,000; high service, $4,500; water-power, $6,000.

Duty of engines: 7,000,000 pounds daily.

GEORGIA.

ROME:

Population: 3,877 inhabitants.

Name of corporation: Rome Water-Works (municipal).

Water obtained from: Well.

Water first introduced: In 1871.

Description of distributing reservoir: Built on a hill 100 feet above city level; 25 feet diameter, 63 feet high; made of boiler-iron.

Sizes of distributing mains: 10 to 4 inches.

Available head: 150 feet (average).

Total length of distributing mains: 5 miles.

Number of water-takers: 350.

Consumption of water: 150,000 gallons per day (estimated).

First cost of water-works: $100,000.

Average annual cost of maintenance and repairs: $2,500.

Number of fire-plugs: 55.

Design and dimensions of pump and water-plungers: Pump, Noble Brothers & Co., Rome, Georgia; bucket-plungers, 42 inches stroke, 14 inches diameter; 15 strokes per minute; diameter of pump-barrel, 14 by 42 inches.

Time pump is run: 8 hours per day.

Time spent in repairs: 60 hours per year.

Description of force-main: 200 feet head on pump.

Description of water-valves: Brass and leather.

Kind of power used: Steam.

Description of boilers: 4 feet, 26 inches; 2 flues; fuel, bituminous coal, 1 pound to 100 gallons water.

Description of engine: Simple; 20 inches diameter, 42 inches stroke, 14 strokes per minute; slide-valves, by eccentric.

Cost of engine: $12,000.

ILLINOIS.

DE KALB:

Population: 1,598 inhabitants.

Style of corporation: Municipal.

Water obtained from: Well.

Capacity of receiving reservoir: 60,000 gallons.

Water first introduced: In 1877.

Available head in main conduit: 55 feet (average).

Sizes of distributing mains: 6 and 4 inches.

Available head in the town: 50 to 75 feet.

Total length of distributing mains: 7,000 feet.

Number of water-takers: 62.

Consumption of water: 12,000 gallons per day (estimated).

First cost of water-works: $32,000.

Average annual cost of maintenance and repairs: $1,500.

Number of fire-plugs: 13.

Design and dimensions of water-plungers: Two plain plungers, 10 inches diameter, 10 inches stroke, 40 strokes per minute; size of pump-barrel, 10 inches diameter.

Time spent in repairs: 60 hours per year.

Description of force-main: 4,000 feet long; 60 feet head on pump.

Kind of power used: Wind and steam.

Description of boilers: 42 inches diameter; 80 pounds pressure; made by Chicago Boiler Works.

Description of engine: Non-condensing, simple; 10 inches diameter, 12 inches stroke, 140 strokes per minute.

Cost of engine: $2,000.

LOCKPORT:

Population: 1,679 inhabitants.
Name of corporation: Lockport Artesian Well Company (private).
Water obtained from: Artesian well.
Cost of dam: $6,000.
Water first introduced: In 1876.
Size of distributing mains: 4 inches.
Available head: 100 feet (average).
Total length of distributing mains: 1 mile
Number of water-takers: 40.
First cost of water-works: $6,000.
Average annual cost of maintenance and repairs: $200.
Number of fire-plugs: 10.
Design and dimensions of pump and water-plunger: Pump made by Hart, Ball & Hart, Buffalo, New York; plunger, 3 inches diameter, 3 feet stroke, 50 strokes per minute.
Time pump is run: 10 hours per day.
Kind of power used: Water.

QUINCY:

Population: 27,268 inhabitants.
Name of corporation: Quincy Water-Works Company (private).
Water obtained from: Mississippi river.
Water first introduced: August, 1873.
Description of distributing reservoirs: Two tanks; aggregate capacity, 180,000 gallons; one has frost-proof jacket, but during winter of 1880–'81, with thermometer at 30° below zero no ice formed in either.
Sizes of distributing mains: 16 to 6 inches.
Available head in the town: 50 feet (average).
Total length of distributing mains: About 7 miles.
Number of water-takers: 254.
Consumption of water: 400,000 gallons per day (estimated).
First cost of water-works: $115,000.
Average annual cost of maintenance and repairs: $4,500.
Number of fire-plugs: 77.
Design and dimensions of pump: McGowan Pump Company, Cincinnati, Ohio; piston-pump; 60 strokes per minute; pump-barrel, 24 by 10 inches.
Time pump is run: 9½ hours per day.
Description of force-main: 1 mile long, 16 inches diameter; 90 pounds pressure.
Description of water-valves: 4 vulcanized-rubber disks, 12 inches diameter, ¾ inch lift.
Kind of power used: Steam.
Description of boilers: Tubular; 6 feet long, 5 feet diameter; 48 flues, 4 inches diameter each; 60 pounds pressure; fuel, bituminous coal.
Description of engine: Non-condensing, cutting off at ⅛ stroke; cylinder, 18 inches diameter; 60 strokes per minute; globe valves.
Cost of engine: $1,500.
Duty of engine: 20,000,000 pounds daily (average).
Remarks: Water impure only during floods, then only from earth and sand sediments.

INDIANA.

ATTICA:

Population: 2,150 inhabitants.
Name of corporation: City Water-Works (municipal).
Water obtained from: Springs.
Total area of water-shed available: 1¼ acre.
Water first introduced: In 1868.
Description of distributing reservoir: Built of sandstone, laid in cement; roofed over; capacity, 55,000 gallons.
Sizes of distributing mains: 8 to 3 inches.
Available head: 150 feet (average); water-supply sometimes deficient.
Total length of distributing mains: 5 miles.
Number of water-takers: 250.

ATTICA—Continued.

Consumption of water: About 55,000 gallons per day (estimated).
First cost of water-works: $40,000.
Average annual cost of maintenance and repairs: $1,500.
Number of fire-plugs: 212.
Design and dimensions of pump and water-plungers: Pump made by Dean Bros., Indianapolis, Indiana; 2 plain plungers, 5 inches diameter, 9 inches stroke, 70 strokes per minute.
Time pump is run: 7 hours per day.
Description of force-main: 150 feet long, 4 inches diameter; 35 pounds pressure on pump.
Description of water-valves: Rubber; size 5 inches, ¾ inch lift.
Kind of power used: Steam.
Description of boilers: No. 1, 42 inches diameter, 10 feet long, 38 3-inch tubes; No. 2, 44 inches diameter, 12 feet long, 9 6-inch tubes.
Description of engine: Ordinary slide-valves; 70 strokes per minute.
Cost of engines: $3,100.

FORT WAYNE:

Population: 26,880 inhabitants.
Name of corporation: Fort Wayne Water-Works (municipal).
Water obtained from: Creek.
Total area of water-shed available: 8 square miles.
Dimensions of dam: 50 feet long.
Cost of dam and reservoir: Reservoir, etc., about $40,000; dam, $1,500.
Water first introduced: December, 1880.
Description of distributing reservoir: Oval; 148 by 208 feet at top, 62 by 112 feet at bottom, 34 feet deep; capacity, 3,611,310 gallons; embankment, 12 feet wide at top; inner slope, 2 to 1; faced with brick, 8 inches thick, laid in cement; exterior slope, 1½ to 1; built of clay.
Sizes of distributing mains: 4,091 feet, 24 inches; 1,991 feet, 20 inches; 5,166 feet, 16 inches; 2,776 feet, 12 inches; 3,140 feet, 8 inches; 82,141 feet, 6 inches; 9,979 feet, 4 inches.
Total length of distributing mains: 25.98 miles.
Number of water-takers: 1,600.
Consumption of water: 700,000 gallons per day (estimated).
First cost of water-works: $275,000.
Average annual cost of maintenance and repairs: $7,000.
Filtering apparatus: Basin made by widening the channel of creek, so as to form a settling basin; area, 1 acre, with banks protected by levee.
Number of fire-plugs: 212.
Design and dimensions of pump and water-plungers: Pump made by Holly Manufacturing Company; plain plungers, four 11 inches diameter, 27 inches stroke; two 10 inches diameter, 24 inches stroke; 24 strokes per minutes; pump-barrel, 11 by 27 inches.
Time pump is run: 24 hours per day.
Description of force-main: 4,200 feet, 24 inches diameter; 2,000 feet, 20 inches diameter; 2,560 feet, 16 inches diameter; 166 feet head, or 60 pounds pressure on pumps.
Description of water-valves: Rubber; 6 inches diameter, ½ inch lift.
Kind of power used: Steam.
Description of boilers: Four tubular; 4½ by 16 feet, with 64 4-inch flues; fuel used, Hocking Valley coal.
Description of engine: Non-condensing, condensing, or compound at will; 19 inches diameter, 27 inches stroke, 24 strokes per minute; slide- and puppet-valves; injection-condenser; single-acting vertical air-pumps.
Cost of engine: $30,500.
Duty of engine: 50,000,000 pounds, daily average; 70,000,000 foot-pounds guaranteed.
Remarks: The disadvantages of direct pumping to mains principally are unequal motion of engines, constant attention necessary, and comparative expensiveness.

LA FAYETTE:

Population: 14,860 inhabitants.

LA FAYETTE—Continued.

Style of corporation: Municipal.
Water obtained from: Wabash river.
Cost of dam: $67,000.
Water first introduced: May, 1876.
Description of main conduit: Diameters, 24 and 16 inches; head, 235 feet (average).
Description of distributing reservoir: Located on upper level of city; its bottom is 208 feet above low water; dimensions, 60 by 120 feet at bottom, 190 by 250 feet at top; slope, 1½ to 1; capacity, 4,500,000 gallons.
Sizes of distributing mains: 16, 12, 10, 8, and 4 inches.
Available head: 100 to 150 feet; water-supply sometimes deficient.
Total length of distributing mains: 19 miles.
Number of water-takers: 600.
Consumption of water: 600,000 gallons per day (estimated).
First cost of water-works: $300,000.
Average annual cost of maintenance and repairs: $11,500.
Number of fire-plugs: 167.
Design and dimensions of pump and water-plungers: Pump made by Clapp & Jones, Hudson, New Jersey; 2 plain plungers, 9$\frac{29}{32}$ inches diameter, 36 inches stroke, 35 strokes per minute; pump-barrel, 9$\frac{15}{16}$ by 36 inches.
Time pump is run: 10 hours per day, 5 days per week.
Description of force-main: 2 miles long, 16 inches diameter; 211 feet head, or 45 pounds pressure on pump.
Description of water-valves: Rubber.
Kind of power used: Steam.
Description of boilers: Steel; 26 feet long, 44 inches diameter; 40 pounds pressure; fuel, slack coal.
Description of engine: Condensing, flat ball-valve; operated by screw.
Cost of engine: $27,000.
Duty of engine: 30,000,000 foot-pounds, daily average.

NEW ALBANY:

Population: 16,423 inhabitants.
Name of corporation: New Albany Water Company (private).
Water obtained from: Ohio river.
Capacity of receiving reservoirs: 3 reservoirs; total capacity, 9,000,000 gallons.
Character and dimensions of dam: Made of clay, lined with brick two layers thick, each layer 6 inches thick; solid puddle-bank, sodding on outside.
Cost of dam: $20,000.
Water first introduced: July, 1876.
Description of main conduit: 4,200 feet long, 16 inches diameter; cast iron.
Discharging capacity: 3,000,000 gallons per day; head, 198 feet (average).
Description of distributing reservoir: Made partly by excavation and partly by embankment; slope, 1½ to 1; banks, clay-puddled; 15 feet deep.
Sizes of distributing mains: 12, 10, 8, and 6 inches.
Available head: 175 to 220 feet.
Total length of distributing mains: 17 miles.
Number of water-takers: 700.
Consumption of water: 500,000 or 600,000 gallons per day (estimated).
First cost of water-works: $175,000.
Average annual cost of maintenance and repairs: $6,000.
Number of fire-plugs: 146.
Design and dimensions of pump and water-plungers: Pump made by F. Shefold, New Albany; two plain plungers; 16 inches diameter, 5 feet stroke, 12 to 14 strokes per minute; pump-barrel, 17 inches.
Time pumps are run: 50 hours per week.
Description of force-main: 4,282 feet long; 270 feet head on pump.
Description of water-valves: 4½ inches diameter, 3 inches lift.
Kind of power used: Steam.

NEW ALBANY—Continued.

Description of boilers: Two 46 inches diameter, 26 feet long; two 17-inch flues, 80 pounds pressure; 10 pounds of water to 1 pound of coal; fuel, Pittsburgh coal.
Description of engine; high-pressure, non-condensing; 26 inches diameter, 6 feet stroke, 12 to 14 strokes per minute; puppet-valves worked by eccentric.
Cost of engine: $15,000.
Duty of engine: 4,187,000 gallons per 100 pounds coal daily; 2,000,000 gallons per day guaranteed.

KENTUCKY.

MAYSVILLE:

Population: 5,220 inhabitants.
Name of corporation: Maysville Water Company (private).
Water obtained from: Ohio river.
Capacity of receiving reservoir: 2,500,000 gallons.
Cost of dam: $20,000.
Water first introduced: In 1880.
Description of main conduit: Iron.
Description of distributing reservoir: Built on hill-side; half excavation and half embankment; base embankment, 18 inches puddle; core, 4-inch brick wall.
Sizes of distributing mains: 14, 12, 10, 8, 6, and 4 inches.
Available head: 340 feet (average).
Total length of distributing mains: 7 miles.
Number of water-takers: 204.
First cost of water-works: $160,000.
Number of fire-plugs: 70.
Design of pump: Pump made by Blake Manufacturing Company, Boston, Massachusetts, 1880.
Description of force-main: 5,000 feet long, 12 inches diameter; 150 pounds pressure on pump.
Kind of power used: Steam.
Description of boilers: Four boilers; two batteries, 26 feet long, 48 inches diameter.
Cost of engine: $30,000.

NEWPORT:

Population: 20,433 inhabitants.
Name of corporation: Newport Water-Works (municipal).
Water obtained from: Ohio river.
Capacity of receiving reservoir: 45,000,000 gallons.
Character and dimensions of dam: 35 feet high, 20 feet wide on top; slopes, 1¾ to 1 and 3 to 1.
Cost of dam: $141,000.
Water first introduced: In 1873.
Description of main conduit: 13,450 feet long, 20 inches diameter; cast iron; head, 174 feet (average).
Description of distributing reservoir: Constructed by dam across two ravines.
Sizes of distributing mains: 16, 10, 8, 6, and 4 inches.
Available head: 132 to 207 feet.
Total length of distributing mains: 16½ miles.
Number of water-takers: 1,583.
Consumption of water: About 20½ gallons per head daily (estimated).
First cost of water-works: $615,000.
Average annual cost of maintenance and repairs: $650.
Number of fire-plugs: 107.
Design and dimensions of pump and water-plunger: Pump made by Cope & Maxwell Manufacturing Company, Hamilton, Ohio, 1873; plain plunger, double-acting, 13 inches diameter, 4 feet stroke, 14 strokes per minute; pump-barrel 18 inches by 5 feet.
Time pump is run: 14 hours per day.
Description of force-main: 1,600 feet long, 24 inches diameter; 350 feet head on pump.
Description of water-valves: Rubber; 14 inches diameter, 1¾ inch lift.
Kind of power used: Steam.
Description of boilers: Two; 24 feet long, 40 inches diameter; 80 pounds pressure; fuel, bituminous coal.

NEWPORT—Continued.

Description of engine: Non-condensing, direct-acting; 26 inches diameter, 4 feet stroke, 14 strokes per minute; slide-valves.

Cost of engine: $12,500.

PLEASANT HILL:

Population: 203 inhabitants.

Style of corporation: Municipal.

Water obtained from: Springs.

Capacity of receiving reservoir: 5,000 gallons.

Description of distributing reservoir: Built of cedar, black locust, and mulberry staves, banded with iron; capacity, 5,000 gallons.

Sizes of distributing mains: 2, 1½, 1, and ½ inches.

Total length of distributing mains: 1 mile.

Number of water-takers: 200.

Consumption of water: 250 gallons per day (estimated).

First cost of water-works: $3,000.

Average annual cost of maintenance and repairs: $50.

Design and dimensions of pump and water-plungers: Pump made by Burnett, Cincinnati, Ohio, 1832; two plain plungers, 4 inches diameter, 4 strokes per minute; pump-barrel, 4 inches diameter.

Time pump is run: 8 hours per day.

Description of force-main: ½ mile long, 3 inches diameter; cast iron; 120 feet head on pump.

Description of water-valves: 2½ inches diameter.

Kind of power used: Horse.

MAINE.

BIDDEFORD:

Population: 12,651 inhabitants.

Name of corporation: Saco Water-Power Company (private).

Water obtained from: Saco river.

Capacity of receiving reservoir: 252,000 gallons.

Character and dimensions of dam: Of granite, where water is taken.

Cost of dam: $20,000.

Description of main conduit: Cast iron; diameter, 12 inches; head, 85 feet (average).

Description of distributing reservoir: Built on eminence, 85 feet above pumps; granite lined with brick and cement; roofed over.

Sizes of distributing mains: 12, 8, and 6 inches.

Available head: 50 feet (average); water-supply seldom deficient.

Fire-plugs: Made by Saco Water-Power machine-shops.

Design of pumps: Fales and Jenk rotaries; W. P. Crocker's twin rotary.

Time pumps are run: Constantly.

Kind of power used: Water.

LEWISTON:

Population: 19,083 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Androscoggin river.

Character and dimensions of dam: Owned and maintained by the Union Water-Power Company.

Cost of dam: $38,824 71.

Water first introduced: In 1878.

Description of main conduit: 2,556 feet long, 24 inches diameter; cast iron.

Description of distributing reservoir: Situated about 2 miles from pumping-station; 200 feet elevation; core of embankment, brick and cement; capacity, 14,000,000 gallons.

Sizes of distributing mains: 24 to 4 inches.

Available head: 54 to 110 pounds.

Total length of distributing mains: About 22 miles.

Number of water-takers: 2,788.

Consumption of water: About 1,000,000 gallons per day; 52 gallons per head.

First cost of water-works: $500,000.

LEWISTON—Continued.

Average annual cost of maintenance and repairs: About $5,000.

Filtering apparatus: Built in arch leading from head-gates to screen-well; area (superficial), 400 feet; sea-gravel and sand 32 inches deep; cleaned once a week.

Number of fire-plugs: 141.

Design and dimensions of pump and water-plungers: Pump made by H. R. Worthington, Brooklyn, New York; 4 plain plungers, 17½ inches diameter, 38 inches stroke, 9 strokes per minute; pump-barrel, 26 inches diameter.

Time pump is run: 222 days in 1880.

Description of force-main: 24 inches diameter; 92 pounds head on pump.

Description of water-valves: Hard rubber; 7 inches diameter, ⅝ to ¾ inch lift.

Kind of power used: Water.

Description of water-wheels: Two Risden turbine; 54 inches; 25 feet head; 80 revolutions per minute.

MASSACHUSETTS.

DANVERS:

Population: 6,598 inhabitants.

Name of corporation: Danvers Water-Works (municipal).

Water obtained from: Middleton and Swan ponds.

Total area of water-shed available: 2,089 acres.

Area of receiving reservoirs: Middleton pond, 106 acres; Swan pond, 69 acres.

Water first introduced: In 1876.

Description of distributing reservoir: Oval, 21 feet deep, nearly vertical walls; owned by state of Massachusetts; capacity, 5,000,000 gallons.

Sizes of distributing mains: 12, 8, 6, and 4 inches.

Available head: 230 feet (average).

Total length of distributing mains: 28½ miles.

Number of water-takers: 1,000.

First cost of water-works: $180,000.

Average annual cost of maintenance and repairs: $4,000.

Number of fire-plugs: 184.

Design and dimensions of pump and water-plungers: Pump, made by H. R. Worthington, New York; 2 plain plungers, 16 inches diameter, 26 inches stroke, 52 strokes per minute.

Time pump is run: 1,800 hours per year.

Description of force-main: 13,879 feet long, 12 inches diameter; 56 to 80 pounds pressure on pump.

Description of water-valves: Worthington's patent.

Kind of power used: Steam.

Description of boilers: Tubular; 16 feet long, 5 feet 4 inches diameter, 56 pounds pressure; fuel used, anthracite furnace coal.

Description of engine: Duplex compound condensing; high-pressure cylinder 21 inches diameter, low-pressure cylinder 43 inches diameter, 26 inches stroke, 52 strokes per minute; balanced slide-valves, each operated by piston of other engine; Worthington's air-pump.

Duty of engine: 56,000,000 to 60,000,000 foot-pounds daily, (average); 50,000,000 foot-pounds guaranteed.

Remarks: Only in one instance has any impurity of water been noticed.

KINGSTON:

Population: 1,524 inhabitants.

Name of corporation: Kingston Aqueduct Association (private).

Water obtained from: Spring, mill privilege.

Water first introduced: In 1804.

Description of main conduit: ½ mile long, 1¼ inch diameter: lead.

Description of distributing reservoir: 20 feet high; stands on a hill; pump at base of hill, 60 feet below stand-pipe.

Size of distributing mains: 1¼ inch.

Total length of distributing mains: ½ mile.

Number of water-takers: 48.

First cost of water-works: $2,500.

KINGSTON—Continued.

Design and dimensions of water-plunger: Single-acting plunger, 3½ inches in diameter, 10 to 18 strokes per minute; pump-barrel, 3½ inches diameter.

Time pump is run: Constantly.

Description of force main: 60 feet head on pump.

Description of water-valves: Plunger-valves, 1¼ inch diameter.

Kind of power used: Water.

Character and dimensions of water-wheel: Overshot, 5½ feet diameter, 8 feet head; 10 to 80 revolutions per minute.

LINCOLN:

Population: 907 inhabitants.

Name of corporation: Lincoln Water-Works (municipal).

Water obtained from: Sandy pond.

Total area of water-shed available: 300 acres.

Area and capacity of receiving reservoir: Pond, 152 acres; 1,300,000 gallons.

Water first introduced: October, 1875.

Description of main conduit: Diameter, 8 inches; wrought iron and cement.

Description of distributing reservoir: Puddled earth; capacity, 1,300,000 gallons.

Size of distributing mains: 6 inches.

Available head: 20 to 80 feet.

Total length of distributing mains: About 3½ miles.

Number of water-takers: 20.

First cost of water-works: About $33,000.

Number of fire-plugs: 11.

Design of pump and water-plungers: Made by H. R. Worthington, New York.

Time pump is run: About 20 hours per week.

Description of force-main: 6,400 feet long, 6 inches diameter; 160 feet head on pump.

Kind of power used: Steam.

Description of boilers: Fuel, anthracite coal.

Description of engine: Simple; 10 inches diameter, 145 strokes per minute.

Cost of engine: $2,500.

LYNN:

Population: 38,274 inhabitants.

Name of corporation: Lynn Water-Works (municipal).

Water obtained from: Streams.

Total area of water-shed available: 1.57 square mile.

Area and capacity of receiving reservoirs: First pond, 63.18 acres, 226,310,942 gallons; second pond, 69.6 acres, 211,491,976 gallons.

Character and dimensions of dams: No. 1, 300 feet long; earthwork, 23 feet high, 15 feet wide on top; slopes, 1½ to 1; puddled clay on inside; retaining-wall on outside, 150 feet long, 18 feet high. No. 2, 250 feet long, 16 feet high, 15 feet wide on top; slope, 1½ to 1; earthwork, with puddle-clay wall through center.

Cost of dams: $75,595.

Water first introduced: In 1871.

Description of main conduit: 2,228 feet long, 18 inches diameter; 5,833 feet long, 22 inches diameter; wrought iron and cement.

Discharging capacity: About 4,000 gallons per minute; head, 17 feet (average).

Description of distributing reservoir: Built on a side hill, partly excavated and partly embankment; inside slopes and bottom puddled with clay; capacity, 20,000,000 gallons; 15 feet deep; water-surface, 177 feet above datum; a 12-inch slope-wall on rubble backing (15 inches thick) on the outside.

Sizes of distributing mains: 16 to 2 inches.

Available head: 150 feet (average).

Total length of distributing mains: 56⅔ miles.

Number of water-takers: 6,753.

Consumption of water: 1,238,289 gallons per day, 49.4 per consumer, 32.3 per inhabitant, exact, in 1880.

First cost of water-works: $1,000,390.

Average annual cost of maintenance and repairs: $9,500.

LYNN—Continued.

Number of fire-plugs: 411.

Design and dimensions of pump and water-plunger: Pump designed by E. D. Lavitt, jr., built by I. P. Morris & Co., Philadelphia; one bucket-plunger, 18½ inches diameter, 7 fee stroke; piston-valve, 22 and 16½ inches diameter, 18½ strokes per minute; pump-barrel, 26$\frac{1}{10}$ inches diameter, 7 feet stroke.

Time pump is run: 2,190 hours per year.

Description of force-main: 1,904 feet long; 166 feet head on pump.

Description of water-valves: Cornish, double-beat; 15⅞ inches diameter of lower seat outside, 10 inches diameter upper seat inside; 2¼ inches lift.

Kind of power used: Steam.

Description of boilers: Horizontal tubular, 16 feet long, 5 feet diameter; 72 3-inch tubes; drum, 6 feet high, 3 feet diameter; 8.58 pounds to 1 pound coal; fuel, anthracite coal.

Description of engine: Compound condensing; high-pressure cylinder 17½ inches diameter, low-pressure cylinder 36 inches diameter, 7 feet stroke, 18.5 strokes per minute; gridiron slide-valves, worked by cams; jet-condenser; air-pump, double-acting, 11¼ inches diameter, 49½ inches stroke.

Cost of engine and pump: $50,000.

Duty of engine: 92,843,506 foot-pounds daily (average); 70,000,000 foot-pounds guaranteed.

Remarks: One pond in summer is tainted by a smell of animal matter, rendering it unfit for domestic use.

SOMERVILLE:

Population: 24,933 inhabitants.

Style of corporation: Municipal.

Water obtained from: Boston water-works.

Water first introduced: In 1876.

Available head: 6 to 130 feet; water-supply sometimes deficient.

Total length of distributing mains: 45 miles.

Number of water-takers: 4,683.

First cost of water-works: $342,608 76 (cost of distribution).

Average annual cost of maintenance and repairs: $8,000.

Number of fire-plugs: 278 (see accompanying report on Boston, p. 17–31).

WALTHAM:

Population: 11,712 inhabitants.

Name of corporation: Waltham Water-Works (municipal).

Water obtained from: Charles river.

Total area of water-shed available: About 200 square miles.

Area and capacity of receiving reservoir: 61,917 square feet; 6,000,000 gallons.

Water first introduced: In 1873.

Description of main conduit: 2,629 feet long, 16 inches diameter; wrought iron lined with cement.

Description of distributing reservoir: Built in natural gorge; puddled dams at ends, oval in shape; ends semicircles, 105 feet radius, joined by straight walls 50 feet long; slopes, 1½ to 1; inner slope lined with granite 12 inches through.

Sizes of distributing mains: 16, 12, 10, 8, 6, 4, and 2 inches.

Available head: About 135 feet (average).

Total length of distributing mains: 23.33 miles.

Number of water-takers: 1,557.

Consumption of water: 411,000 gallons per day (average).

First cost of water-works: $223,000.

Filtering apparatus: Basin, ¼ acre, 8½ feet deep, 30 feet from bank of Charles river; gravel; no cleaning.

Number of fire-plugs: 152.

Design and dimensions of pumps and water-plungers: Two pumps, made by H. R. Worthington, New York, in 1873 and 1880; two plain double-acting plungers, 14 inches diameter, 18 inches stroke, 45 strokes per minute.

Time pumps are run: 14 hours per day, 5 days per week.

Time spent in repairs: 12 hours per year (average).

Description of force-main: 2,600 feet long, 16 inches diameter. 164 feet head on pumps.

WALTHAM—Continued.

Description of water-valves: Rubber, weighted on gridiron seats; 6¼ inches diameter, ½-inch lift.

Kind of power used: Steam.

Description of boilers: Horizontal return-tubular; 16 feet long, 5 feet diameter; 55 pounds pressure (average); fuel used, hard coal.

Description of engine: Compound condensing; high-pressure cylinder 14 inches diameter, low-pressure cylinder 24 inches diameter, 18 inches stroke, 90 strokes per minute; globe-valves, operated by wheel and spindle; 4 air-pumps, 9 by 13½ inches; jet-condenser, 16 by 22 inches.

Cost of engine and pumps: $17,150.

Duty of engine: 45,000,000 foot-pounds guaranteed.

MISSOURI.

SAINT JOSEPH:

Population: 32,431 inhabitants.

Name of corporation: Saint Joseph Water Company (private).

Water obtained from: Missouri river.

Water first introduced: December, 1880.

Description of distributing reservoir: Three basins; middle basin used as a subsiding reservoir; water from main received in well, whence it passes into middle or either basin or into mains direct; capacities, subsiding basin, 2,000,000 gallons; south district basin, 4,000,000 gallons; north district basin, 6,000,000 gallons.

Sizes of distributing mains: 20, 16, 12, 10, 8, 6, and 4 inches.

Available head: 116 to 314 feet.

Total length of distributing mains: 24 miles.

Number of water-takers: 134.

Consumption of water: 600,000 gallons per day (estimated).

First cost of water-works: $700,000.

Filtering system: Use subsiding basin.

Number of fire-plugs: 184.

Design and dimensions of pumps and water-plungers: Two pumps, made by H. R. Worthington, Brooklyn, New York, in 1880–'81; main engine, two plungers, 17½ inches diameter, 36 inches stroke, 58 strokes per minute; diameter of pump-barrel, 17½ inches; auxiliary engine, two plungers, 10 inches diameter, 15 inches stroke, 138.8 strokes per minute; diameter of pump-barrel, 10 inches.

Description of force-main: 1,196 feet long, 16 inches diameter. 127 pounds pressure on pumps.

Description of water-valves: 64 rubber; 4-inch opening, ¾ inch lift.

Kind of power used: Steam.

Description of boilers: 3 tubular; 59 4-inch tubes; shell, 64 inches diameter, 16 feet long; fuel used, semi-bituminous coal.

Description of engine: Compound condensing; cylinders 25 and 13.3 inches diameter, 36 and 38 inches stroke, 58 strokes per minute; balanced slide-valves, worked from rock-shaft; spray-condenser; four air-pumps, 18¾ inches diameter, 15 inches stroke.

Cost of engine and pumps: $30,000.

NEW HAMPSHIRE.

NASHUA:

Population: 13,397 inhabitants.

Name of corporation: Pennichucks Water-Works (private).

Water obtained from: Small stream.

Total area of water-shed available: About 30 square miles.

Character and dimensions of dams: One wood and stone, 15 feet fall; one stone, 17 feet fall; use water for power twice (two pumping-houses).

Water first introduced: In 1855.

Description of distributing reservoir: Capacity, 1,500,000 gallons.

Sizes of distributing mains: 16 to 4 inches.

Available head: 100 feet (average).

Total length of distributing mains: About 20 miles.

NASHUA—Continued.

Number of water-takers: 1,021.

Consumption of water: 1,000,000 gallons per day (estimated).

First cost of water-works: $60,000.

Average annual cost of maintenance and repairs: About $10,000.

Number of fire-plugs: 55.

Design and dimensions of pump and water-plunger: Old pump removed in 1881, and Lang's substituted; made at Burlington, Vermont; plain plunger, 12 inches diameter, 28 inches stroke, 24 strokes per minute; pump-barrel, 12 inches diameter.

Time pump is run: Constantly.

Description of force-main: 5,200 feet long; head on pump, 132 feet.

Description of water-valves: Lang's patent.

Kind of power used: Water; steam in case of drought.

Description of water-wheels: 1 Jonval turbine, 15 feet head, 94 revolutions per minute; 10 gallons of water used to lift 1 gallon to reservoir; 2 Swain wheels to Lang pump, 24 feet head, 200 revolutions per minute, 8 gallons used to lift 1 gallon to reservoir.

Description of boilers: Hinkley's patent locomotive boiler; 65 pounds pressure; fuel, hard coal.

Description of engine: Cylinder, 14 by 36 inches; 60 strokes per minute; puppet-valve, worked by bevel-gear.

Cost of engine and pumps: $14,500.

Duty of engines: 1,000,000 gallons in 24 hours; 3,000,000 gallons in 24 hours guaranteed.

NEW JERSEY.

BRIDGETON:

Population: 8,722 inhabitants.

Style of corporation: Municipal.

Water obtained from: East Lake pond (Cedar Swamp-water).

Water first introduced: December, 1877.

Description of distributing reservoir: Area, 135 feet square; clay banks lined with brick; slope, 1¾ to 1; capacity, 1,350,000 gallons.

Sizes of distributing mains: 16 and 2 inches.

Available head: 15 to 40 pounds.

Total length of distributing mains: 11¼ miles.

Number of water-takers: 540.

Consumption of water: 108,000 gallons per day (average).

First cost of water-works: $69,000.

Average annual cost of maintenance and repairs: $1,445.

Number of fire-plugs: 77.

Design and dimensions of pump and water-plungers: Worthington, 1877, Brooklyn, New York; two plain plungers, 13 inches diameter, 18 inches stroke, 55 strokes per minute; pump-barrel, 13 inches diameter.

Time pump is run: 807 hours per year in 1880.

Description of force-main: 2,300 feet long, 16 inches diameter; 87 feet head on pump (average).

Description of water-valves: Rubber, 6 inches diameter, ¼ inch lift.

Kind of power used: Steam.

Description of boilers: Tubular, 12 feet long, 42 inches, diameter; 45 pounds pressure; fuel used, hard coal.

Description of engine: Compound duplex; high-pressure cylinder 14¼ inches diameter, low-pressure cylinder 30 inches diameter, 18 inches stroke, 55 strokes per minute; D slide-valve with cut-off at ½ inch stroke; two air-pumps, 10 inches bore, 12 inches stroke; jet condenser.

Cost of engine and pump: $10,500.

CAPE MAY:

Population: 1,699 inhabitants.

Style of corporation: Municipal.

Water obtained from: Wells.

Capacity of receiving reservoir: 40,000 to 60,000 gallons.

CAPE MAY—Continued.

Water first introduced: In 1876.
Description of main conduit: Diameters, 12, 10, and 8 inches; cast iron; 20 pounds pressure.
Sizes of distributing mains: 12, 10, and 8 inches.
Total length of distributing mains: 3 miles.
Number of water-takers: 200.
Consumption of water: 100,000 gallons per day (estimated).
First cost of water-works: $5,000.
Number of fire-plugs: 65.
Design and dimensions of pump and water-plunger: R. D. Wood & Co., Millville, New Jersey; plain plunger 20 inches diameter, 65 inches stroke, 65 strokes per minute; pump-barrel, 24 by 16 inches.
Time pumps is run: 24 hours four months; 7 hours eight months.
Description of force-main: 20 pounds pressure on pump.
Kind of power used: Steam.
Description of boilers: Upright; 60 inches diameter, 6 feet flues; fuel, pea-coal.
Description of engine: Simple; 65 strokes per minute; common globe-valves.
Cost of engine and pump: $1,900.
Duty of engine: 400 gallons per minute daily guaranteed.

JERSEY CITY:

Population: 120,722 inhabitants.
Name of corporation: Jersey City Water-Works (municipal).
Water obtained from: Passaic river.
Total area of water-shed available: 981 square miles.
Water first introduced: In 1853.
Description of main conduit: 6½ miles long, 36 and 24 inches diameter; cast iron and cement.
Sizes of distributing mains: 36 and 26 inches.
Available head: 30 to 90 feet.
Total length of distributing mains: About 13.5 miles.
Consumption of water: 80 gallons per head (estimated).
Design of pumps and water-plungers: 3 Cornish and 3 Worthington.
Kind of power used: Steam.

MOUNT HOLLY:

Population: 4,621 inhabitants.
Name of corporation: Mount Holly Water Company (private).
Water obtained from: Rancocas river.
Capacity of reservoirs: 2 basins, 250,000 gallons each.
Cost of dam: $30,000.
Water first introduced: In 1851.
Description of main conduit: Diameter, 6 inches; iron.
Description of distributing reservoir: 2 basins; about 101 feet above tide-water; puddled clay and brick walls.
Size of distributing mains: 6 inches.
Available head: 40 to 90 feet.
Total length of distributing mains: 1,800 feet.
Number of water-takers: About 310.
Consumption of water: 168,000 gallons per day (estimated).
First cost of water-works: $24,000.
Average annual cost of maintenance and repairs: About $2,000.
Number of fire-plugs: 29.
Design and dimensions of pumps and water-plungers: One plain horizontal pump, plunger 6 inches diameter, 3 feet stroke, 30 strokes per minute; one Worthington duplex pump, plunger 10 inches diameter, 18 inches stroke, 66 strokes per minute.
Time pumps are run: 4 hours per week.
Time spent in repairs: None; apparatus duplicate.
Description of force-main: 1,800 feet long; 41 pounds pressure (standing) and 60 pounds pressure (running) on pumps.
Description of water-valves: Rubber (small spring).
Kind of power used: Steam.
Description of boilers: 1 Harrison, 20 horse-power; 1 tubular, 14 feet long, 40 inches diameter.

MOUNT HOLLY—Continued.

Description of engines: 1 condensing; 1 non-condensing; high-pressure 12 inches diameter, 18 inches stroke, low pressure 24½ inches diameter; 66 strokes per minute on condensing engine; plain slide-valves; air-pump, 8-inch bore, 18 inches stroke; jet-condenser, 12 inches diameter, 36 inches long.
Cost of engines and pumps: $14,000.
Duty of engines: 200,000 gallons against 60 pounds pressure, with 900 pounds coal daily.

PASSAIC:

Population: 6,532 inhabitants.
Name of corporation: Acquackanouck Water Company (private).
Water obtained from: Passaic river.
Capacity of reservoir: About 1,000,000 gallons.
Water first introduced: In 1872.
Description of distributing reservoir: Area 10 feet diameter, 7½ feet deep.
Sizes of distributing mains: 8 and 6 inches.
Total length of distributing mains: About 9 miles.
Number of water-takers: 250.
Consumption of water: 250,000 gallons per day (estimated).
Average annual cost of maintenance and repairs: $8,498 17.
Number of fire-plugs: 83.
Design and dimensions of pump and water-plunger: Pump made by C. Carr, Trenton, New Jersey; one plain plunger, 12 inches diameter, 5 feet stroke, 14 strokes per minute; pump-barrel, 3 inches diameter.
Time pump is run: 10 or 12 hours per day.
Description of force-main: 5,831 feet long, 12 inches diameter; 45 pounds head on pump.
Description of water-valves: 4 side-buckets, 12 by 18 inches diameter, 8 inches lift.
Kind of power used: Steam.
Description of boilers: Tubular; 16 feet long, 50 pounds pressure; fuel, stove and nut coal.
Description of engine: Simple; cylinder 11 inches diameter, 3 feet stroke, 60 strokes per minute; slide-valves.
Cost of engine and pump: About $8,000.

PATERSON:

Population: 51,031 inhabitants.
Name of corporation: Passaic Water Company (private).
Water obtained from: Passaic river.
Capacity of reservoir: 18,000,000 gallons.
Character and dimensions of dam: Stone and timber, 4 feet high; total head and fall on turbine wheel, 28 feet.
Water first introduced: In 1857.
Description of distributing reservoirs: One with stone wall inside, earth outside; two built with clay puddle-wall and clay bottom, paved on inside.
Sizes of distributing mains: 20, 16, 12, 10, 8, 6, and 4 inches.
Available head: 25 pounds (average); water-supply sometimes deficient.
Total length of distributing mains: About 40 miles.
Number of water-takers: 2,635.
Consumption of water: 110 gallons per head per day.
First cost of water-works: $800,000.
Average annual cost of maintenance and repairs: $12,000.
Number of fire-plugs: 480.
Design and dimensions of pumps and plungers: Paterson Steam Engine Company, three plain single pumps, double-acting, 6 feet stroke; H. R. Worthington, New York, one duplex, 18 inches stroke; all cylinders are 18 inches diameter, 12 to 15 strokes per minute.
Time pumps are run: 23 hours per day.
Time spent in repairs: 1 hour per day (average).
Description of force-main: 700 feet long, 16 inches diameter; 600 feet long, 16 inches diameter, 68 feet head on pumps; 110 feet long, 12 inches diameter, 30 pounds pressure on pumps.
Description of water-valves: Rubber: 1st, 12 inches diameter, ¾ inch lift; 2d, 6 inches diameter, ¾ inch lift.

PATERSON—Continued.

Kind of power used: Steam and water.

Description of water-wheels: Built by Stout, Mills, & Temple, Dayton, Ohio; one 54 inches diameter, 8 feet head, 64 revolutions per minute; one 48 inches diameter, 28 feet head, 135 revolutions per minute; 10 gallons of water required to lift one gallon to reservoir (average).

Description of boilers: Two horizontal tubular, 15 feet long; 46 3-inch tubes; fuel, egg-coal.

Description of engine: Condensing; 24 inches diameter, 4 feet stroke, 40 strokes per minute; Hewes' patent valves; surface condenser.

Cost of engine and pumps: $40,000.

Remarks: Water pronounced very pure by silk-dyers, who require the best.

TRENTON:

Population: 29,910 inhabitants.

Name of corporation: Trenton Water-Works (municipal).

Water obtained from: Delaware river above tide-water.

Cost of dam: $15,000.

Water first introduced: In 1855.

Description of distributing reservoir: Open reservoir.

Sizes of distributing mains: 16 to 2 inches.

Available head: 6 to 85 feet.

Total length of distributing mains: 35 miles.

Number of water-takers: About 5,000.

Consumption of water: 1,250,000 gallons per day (estimated).

First cost of water-works: $100,000.

Average annual cost of maintenance and repairs: $8,830.

Filtering apparatus: 60 by 100 feet area; tile at bottom; 4 layers of gravel, each layer diminishing 1 foot of river; sand on top; cleaned once a year.

Number of fire-plugs: 200.

Design and dimensions of pumps and water-plungers: Pumps made by William Wright, Newburg, New York, and Charles Carr, Trenton, New Jersey; bucket-plungers 16 inches diameter, 5 feet stroke, 20 strokes per minute; pump-barrel, 16 inches diameter.

Time pumps are run during the year: Wright engine and pump, 1,560 hours; Carr engine and pump, 185 hours; water-wheel and pump, 7,249 hours; total, 8,994 hours.

Time spent in repairs: 244¾ hours per year.

Description of force-main: ⅞ mile long, 16 inches diameter; ⅞ mile long, 10 inches diameter; 50 pounds pressure on pumps.

Description of water-valves: Wright, perpendicular; Carr, hinge.

Kind of power used: Steam and water.

Description of water-wheel: One Ohio turbine, 4 feet diameter, 14 feet head, 20 revolutions per minute; 8 gallons of water required to lift 1 gallon to reservoir.

Fuel used: Plymouth broken coal.

Description of engine: Condensing compound; high-pressure cylinder 12 inches diameter, low-pressure cylinder 16 inches diameter, 5 feet stroke each, 20 strokes per minute; Wright's automatic valves.

Cost of engine and pumps: $30,000.

Duty of engine: Capacity of Wright's engine and pump, 2,000,000 gallons in 24 hours; actual amount pumped yearly by all the pumps, 596,271,297 gallons; water-wheel pumps alone 448,930 gallons.

NEW YORK.

COHOES:

Population: 19,416 inhabitants.

Name of corporation: Cohoes Water-Works (municipal).

Water obtained from: Mohawk river.

Character and dimensions of dam: 144 feet long, 9 feet high (average); stone, capped with limestone; built diagonally across Mohawk river.

Cost of dam: $160,000.

Water first introduced: In 1859.

Description of main conduit: Diameter, 16 and 12 inches; cast iron; head, 130 to 245 feet.

COHOES—Continued.

Description of distributing reservoirs: On elevation; one built in clay soil and the other in clay and gravel; capacity, 4,000,000 and 8,000,000 gallons.

Sizes of distributing mains: 16 to 4 inches.

Available head: 130 to 240 feet.

Total length of distributing mains: About 12 miles.

Consumption of water: 30 gallons per head per day (estimated).

First cost of water-works: $160,000.

Average annual cost of maintenance and repairs: $13,000 to $15,000.

Number of fire-plugs: 135.

Design and dimensions of pumps and water-plungers: Geyelin, Philadelphia; built at Cohoes in 1858–'59 and 1868–'69; two plain plungers, 10 and 10 inches diameter, 5 and 6 feet stroke, 12 to 16 strokes per minute; pump-barrels, 10 inches by 5 feet, 16 inches by 6 feet.

Time pumps are run: Almost constantly.

Time spent in repairs: About five days per year.

Description of force-main: 1,250 feet long, 10 inches diameter; 3,400 feet long, 16 inches diameter; 20 to 70 pounds pressure on pumps.

Description of water-valves: Clack-valves.

Kind of power used: Water.

Description of water-wheels: 2 Jonval turbines, one 4 feet diameter, one 3 feet 6 inches diameter, 30 and 40 horse-power; 14 feet head; 70 revolutions per minute; 12½ gallons required to lift 1 gallon to reservoir.

Remarks: Water impure only after freshets.

HUDSON:

Population: 8,670 inhabitants.

Name of corporation: Hudson Water-Works (municipal).

Water obtained from: Hudson river.

Capacity of receiving reservoir: 4,000,000 gallons.

Water first introduced: In 1874.

Description of conduit: 7,215 feet long, 12 inches diameter; iron; head, 130 feet (average).

Description of distributing reservoir: Area at crest line, 32,696 square feet; 20 feet deep; capacity, 3,200,000 gallons.

Sizes of distributing mains: 12, 6, 4, and 3 inches.

Available head: 80 pounds (average).

Total length of distributing mains: 12 7/10 miles.

Number of water-takers: 888.

Consumption of water: 830,000 gallons per day (average).

First cost of water-works: $250,000.

Average annual cost of maintenance and repairs: $10,000.

Filtering system: 13½ feet deep; area at crest, 15,081 square feet; surface of sand, 9,081 feet; stone gravel; cleaned every six weeks (average).

Number of fire-plugs: 177.

Design and dimensions of pump and water-plungers: Clapp & Jones, Hudson, New York, 1874; 2 plain plungers, 8 inches diameter, 36 inches stroke, 34 strokes per minute; pump barrel, 36 by 8 inches.

Time pump is run: 12 hours per day (average).

Time spent in repairs: 1 hour per day (average).

Description of force-main: 7,215 feet long; 311.9 feet head on pump.

Description of water-valves: Rubber; made by Clapp & Jones.

Kind of power used: Steam.

Description of boilers: Tubular; 16 by 5½ feet; 40 pounds pressure, 8 pounds by 1 pound coal; fuel, Pittston coal.

Description of engine: Condensing; 36 by 25 inches, 34 strokes per minute; slide-valves; jet-condenser, 15 by 26 inches; lifting-pump.

Cost of engine and pump: $34,000.

Duty of engine: 77,000,000 foot-pounds daily; 50,000,000 foot-pounds guaranteed.

LYONS:

Population: 3,820 inhabitants.

Name of corporation: Rawley Water-Works (private).

Water obtained from: Springs.

LYONS—Continued.

Description of reservoir: Large cistern, 40 by 60 feet, 12 feet deep.
Cost of dam: $3,500.
Water first introduced: September, 1878.
Description of main conduit: 1,200 feet long; head, 70 feet (average).
Sizes of distributing mains: 4, 2, and 1½ inches.
Available head: 70 feet (average).
Total length of distributing mains: About 7,000 feet.
Number of water-takers: 36.
Consumption of water: 3 to 20 barrels per day.
First cost of water-works: About $3,500.
Average annual cost of maintenance and repairs: $300.
Design and dimensions of pump and water-plungers: Made by M. V. B. Rowley; double-acting 2-cylinder, 40 to 60 strokes per minute; pump-barrel, 2 and 4 by 7 inches.
Kind of power used: Wind-mill.

OSWEGO:

Population: 21,116 inhabitants.
Name of corporation: Oswego Water Company (private).
Water obtained from: Oswego river.
Water first introduced: In 1869.
Description of distributing reservoirs: Two in embankment; no puddling, faced with riprap; eastern, 325 by 600 feet, 15 feet deep; slope, 1 to 1; western, nearly rectangular, 500 by 700 by 225 by 275 feet; area, 4.922 acres; depth, 15 feet; cobblestone and sand division-wall in reservoirs for filtration.
Sizes of distributing mains: 8, 6, 4, and 3 inches.
Total length of distributing mains: 16 miles.
Number of water-takers: 600.
Consumption of water: 1,000,000 gallons per day.
First cost of water-works: $462,500.
Average annual cost of maintenance and repairs: $27,300.
Number of fire-plugs: 167.
Design and dimensions of pumps and water-plungers: Two made by H. Storer, New York, in 1869; two plain piston plungers to each, 10½ inches diameter, 3 feet stroke, 56 strokes per minute.
Time pumps are run: Constantly.
Description of force-mains: Western reservoir, two cast-iron pipes, one 8 inches and the other 10 inches diameter, each 1,450 feet long; eastern reservoir, one 4,100 feet long, 10 inches diameter, and one 3,600 feet long, 8 inches diameter; 300 feet head on pumps, each.
Description of water-valves: Two square rubber flap, 5½ by 7 inches, at each end of the pump-cylinders, each ⅞ inch thick; free lift.
Kind of power used: Water.
Description of water-wheels: Two Storer patent, 5 feet diameter, 3 feet high, 14½ feet head, 56 revolutions per minute.

PEEKSKILL:

Population: 6,893 inhabitants.
Name of corporation: Peekskill Water-Works (municipal).
Water obtained from: Oscawana lake.
Total area of water-shed available: 30,000 acres.
Capacity of receiving reservoir: 31,000,000 gallons.
Character and dimensions of dam: Small one across stream leading from lake; logs and earth, with sheathing boards, to give elevation to stream to drive wheels.
Cost of dam: $24,721 25.
Water first introduced: In 1872.
Description of main conduit: 221 feet square flue; wood; head, 15 feet (average).
Description of distributing reservoir: Excavated and riprapped on sides, excepting north side, which has dam; clay and puddle trench and riprapped.
Sizes of distributing mains: 12 to 4 inches.
Available head: 110 to 120 pounds.
Consumption of water: 200,000 gallons (estimated).
First cost of water-works: $136,150.

PEEKSKILL—Continued.

Averaeg annual cost of maintenance and repairs: About $1,680.
Number of fire-plugs: 76.
Design and dimensions of pump and water-plunger: Flander's patent, made by Vergennes Machine Company, Vermont, 1873–'74; one plain plunger, 11$\frac{1}{16}$ inches diameter, 16 feet stroke, 24 strokes per minute.
Time pump is run: 10 hours per day.
Time spent in repairs: 5 days per year.
Description of force-main: ¾ mile long, 12 inches diameter; 155 pounds pressure on pump.
Kind of power used: Water.
Description of water-wheels: Two American turbines, made by Stout, Mills, & Temple; 48 inches and 36 inches diameter; 34 gallons of water required to lift 1 gallon to reservoir.

WEST TROY:

Population: 8,820 inhabitants.
Name of corporation: West Troy Water-Works Company (private).
Water obtained from: Mohawk river and surface-water.
Total area of water-shed available: 700 acres.
Area and capacity of reservoir: 10 to 12 acres; 70,000,000 gallons.
Character and dimensions of dams: 1,200 feet long, made of stone, riprapped, with timber frame and plank sheathing; head, 7 feet; reservoir dam; 250 feet breadth at base, 50 feet high; earth.
Available head: 110 to 120 pounds.
Cost of dams: $250,000.
Water first introduced: In 1877.
Description of main conduit: 16 inches diameter; wrought iron, cement-lined inside and out; head, 180 feet (average).
Description of distributing reservoir: It is a natural ravine.
Sizes of distributing mains: 16 and 4 inches.
Available head: About 160 feet (average).
Total length of distributing mains: 14 miles.
Number of water-takers: About 270.
Consumption of water: 1,000,000 gallons per day (estimated).
First cost of water-works: $250,000.
Number of fire-plugs: 100.
Design and dimensions of pumps and water-plunger: Flander's pump, made at Vergennes, Vermont; 2 cylinders, double-acting; 16 strokes per minute (average); pump barrel, 14 inches diameter.
Time pump is run: 11 months per year.
Description of main conduit: ½ mile long; 59 pounds pressure on pump.
Kind of power used: Water.
Description of water-wheels: American turbine, 72 inches diameter, made by Stout, Mills, & Temple, Dayton, Ohio; 6 feet head, 17 revolutions per minute.
Remarks: Water a little hard, on account of rocky bed over which it flows.

OHIO.

BELLAIRE:

Population: 8,025 inhabitants.
Name of corporation: City Water-Works (municipal).
Water obtained from: Ohio river.
Character and dimensions of dam: One across front of reservoir; stone wall filled and puddled, 23 feet from river bed.
Water first introduced: In 1872.
Description of distributing reservoir: Semi-circular, with dam across front; excavated in side hill; capacity, 3,000,000 gallons.
Sizes of distributing mains: 12 to 3 inches.
Available head: 65 pounds (average).
Total length of distributing mains: 9 miles.
Number of water-takers: 1,200.
Consumption of water: 578,835 gallons per day (estimated).
First cost of water-works: $100,000.
Average annual cost of maintenance and repairs: About $4,000.
Number of fire-plugs: 75.

BELLAIRE—Continued.

Design and dimensions of pump and water-plungers: Made by Hobbs, Taylor, & Co., Wheeling, West Virginia; four plain plungers, 12 inches diameter, 12 strokes per minute; pump-barrel, 12 by 48 inches.

Description of force-main: 1,475 feet long, 12 inches diameter; 104 pounds pressure on pump.

Description of water-valves: Iron with leather seat; 12 inches diameter, 2 inches lift.

Kind of power used: Steam.

Description of boilers: One tubular, 14 feet long, 48 inches diameter; 60 3-inch flues; fuel, finest slack.

Description of engine: High-pressure; 18 inches diameter, 30 inches stroke, 40 strokes per minute; globe-valves.

Duty of engine: 3,898,150 foot-pounds daily.

Remarks: Oil-refinery in Wheeling City makes water impure at low water.

EAST LIVERPOOL:

Population: 5,568 inhabitants.

Name of corporation: East Liverpool Water-Works (municipal).

Water obtained from: Ohio river.

Capacity of reservoir: 2,500,000 gallons.

Cost of dam: $6,000.

Water first introduced: November, 1880.

Description of distributing reservoir: 116 feet square on top, 68 feet square on bottom, 23 feet deep; made partly by excavation and partly by embankment of guard work; lined with brick and cement.

Sizes of distributing mains: 10, 8, 6, and 4 inches.

Available head: 100 to 265 feet; water-supply sometimes deficient.

Total length of distributing mains: About 5 miles.

Number of water-takers: 450.

First cost of water-works: $36,000.

Average annual cost of maintenance and repairs: $5,000.

Number of fire-plugs: 40.

Design and dimensions of pump and water-plungers: Made by Maxwell Manufacturing Company, Hamilton, Ohio, 1879; two plain plungers, 10 inches diameter, 3 feet stroke, 20 strokes per minute; pump-barrel 10 inches diameter.

Time pump is run: 8 hours per day, 4 days per week.

Description of force-main: 900 feet long.

Description of water-valves: Gum; 4 inches diameter, 3 inches lift.

Kind of power used: Steam.

Description of boilers: Two flue; 6 flues to each.

Description of engine: Compound; 14 by 22 inches diameter, 3 feet stroke, 20 strokes per minute.

Cost of engine and pump: $6,000.

Duty of engine: 3,300,000 foot-pounds in 22 hours.

PENNSYLVANIA.

ALLEGHENY:

Population: 78,682 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Allegheny river.

Capacity of reservoir: 10,000,000 gallons.

Water first introduced: In 1848.

Description of distributing reservoir: Parallelogram in shape, with cross-section stone wall dividing it into two compartments, each containing about 5,000,000 gallons, with one influent; effluent chamber constructed at ends of division-wall.

Size of distributing mains: 20 inches.

Available head: 92 feet (average); water-supply sometimes deficient.

Total length of distributing mains: 50 miles.

Number of water-takers: 13,000.

Consumption of water: 8,000,000 gallons per day (estimated).

Average annual cost of maintenance and repairs: $30,000.

ALLEGHENY—Continued.

Design and dimensions of pumps and water-plungers: One Lowry's, designed by Hartupee, Pittsburgh, Pennsylvania; two plain plungers, 30 inches diameter, 8 feet stroke, 8 strokes per minute; pump-barrel, 30½ inches diameter; four Knapp & Tutton pumps, Pittsburgh, Pennsylvania; four double-acting piston-plungers, 12¼ inches diameter, 8 feet stroke, 16 strokes per minute; pump-barrel, 12¼ inches diameter.

Time pumps are run: Constantly.

Time spent in repairs: 600 hours per year.

Description of force-main: 580 feet long, 30 inches diameter; 215 feet head on pumps.

Description of water-valves: Lowry; disk, 15 inches diameter, 1½ inches lift; Knapp & Tutton hinge.

Kind of power used: Steam.

Description of boilers: Four 26 feet long, 48 inches diameter; two 16-inch flues; 8 pounds of water to 1 pound of coal; fuel, bituminous coal.

Description of engines: Simple; Lowry's; 44 inches diameter, 11 feet stroke, 8 strokes per minute; balance disk-valve by ordinary gear. Knapp & Tutton's, 20½ inches diameter, 8 feet stroke, 16 strokes per minute.

Duty of engines: Lowry's, 36,000,000 foot-pounds daily.

Remarks: Water sometimes impregnated with oil.

BUTLER:

Population: 3,163 inhabitants.

Name of corporation: Butler Water-Works Company (private).

Water obtained from: Connoquenessing creek.

Water first introduced: November, 1878.

Description of distributing reservoir: Area, 121 by 121 feet bottom, 160 by 160 feet top, 18 feet high to flow-line; capacity, 2,500,000 gallons.

Sizes of distributing mains: 10, 8, and 4 inches.

Available head: 100 pounds (average).

Total length of distributing mains: 5 miles.

First cost of water-works: $49,000.

Number of fire-plugs: 41.

Design and dimensions of pump and water-plunger: Epping pump, built by Thompson, Epping, & Carpenter, Pittsburgh, Pennsylvania, 1878; one plain plunger; 9½ inches diameter, 3 feet stroke, 24 strokes per minute; pump-barrel 9¼ inches diameter.

Time pump is run: About 3 hours per week.

Description of force-main: 2,900 feet long, 12 inches diameter, 13 pounds pressure on pump.

Description of water-valves: Puppet; brass, faced with leather, 4 by 12 inches, ½ inch thick, ¾ inch lift.

Kind of power used: Steam.

Description of boilers: Double-flue; 20 feet long, 38 inches diameter; flues 15 inches diameter; fuel, bituminous coal.

Description of engine: Simple; 20 inches diameter, 3 feet stroke, 48 strokes per minute; slide-valves operated with cams.

Cost of engine and pump: $5,000.

Duty of engine: 100 pounds coal raise 5,500 gallons daily (average).

CARLISLE:

Population: 6,209 inhabitants.

Name of corporation: Carlisle Gas and Water Company (private).

Water obtained from: Conedogwinit creek.

Character and dimensions of dams: Wooden; 200 feet long between abutments; meadow dam, 150 feet long.

Water first introduced: In 1854.

Description of main conduit: 1¼ mile long, 6 inches diameter; head, 52 feet (average).

Description of distributing reservoirs: Two, 120 feet square each, 11 feet deep.

Sizes of distributing mains: 8, 6, and 4 inches.

Available head: 52 feet (average).

Total length of distributing mains: 8 miles.

Number of water-takers: 510.

CARLISLE—Continued.

Consumption of water: 30 gallons per head (estimated).
First cost of water-works: About $80,000.
Average annual cost of maintenance and repairs: $200.
Number of fire-plugs: 61.
Design and dimensions of pump and water-plungers: Made by A. F. Smith, Chambersburg, Pennsylvania, 1854; two bucket-plungers, 7½ inches diameter, 18 inches stroke, 26 strokes per minute; pump-barrel 8 feet high, 24 inches diameter.
Time pump is run: Constantly.
Description of force-main: 1¼ mile long, 6 inches diameter; 40 pounds pressure on pump.
Description of water-valves: Ordinary check; 8 inches diameter, 1¼ inch lift.
Kind of power used: Water.
Description of water-wheel: One turbine; 56 inches diameter (Leffel turbine), 4 feet head, 26 revolutions per minute.
Remarks: Sometimes, after heavy rains and sudden thaws, the water is muddy.

CHESTER:

Population: 14,997 inhabitants.
Name of corporation: South Ward Water-Works of Chester, (municipal).
Water obtained from: Delaware river.
Capacity of reservoir: 1,500,000 gallons.
Water first introduced: In 1868.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 40 pounds (average).
Total length of distributing mains: 15 miles.
Number of water-takers: 1,600.
Consumption of water: 300,000 gallons per day (estimated), or 20 gallons per head.
First cost of water-works: $84,000.
Average annual cost of maintenance and repairs: $8,000.
Number of fire-plugs: 64.
Design and dimensions of pump and water-plungers: Made by Robert Wetherill & Co., Chester, Pennsylvania, in 1879; 2 plain plungers, 9¼ inches diameter, 30 inches stroke, 47 strokes per minute.
Time pump is run: 70 hours per week.
Description of force-main: 1 mile long, 12 inches diameter; 35 to 43 pounds pressure on pump.
Description of water-valves: Rubber, 3½ inches diameter, ¾-inch lift.
Kind of power used: Steam.
Description of boilers: 2 sets, double deck; 10 feet 1½ inch long, 42 inches diameter; about 90 horse-power; fuel used, pea coal.
Description of engine: Compound condensing, 20 and 9 inches diameter, 36 inches stroke, 47 strokes per minute; Corliss valves; air-pump, jet-condenser.
Cost of engine and pump: $10,000.
Duty of engine: 800,000 gallons daily; 2,500,000 gallons in 24 hours guaranteed.

CLARION:

Population: 1,169 inhabitants.
Name of corporation Clarion Water Company (private).
Water obtained from: Clarion river.
Capacity of reservoir: 90,000 gallons.
Water first introduced: In 1875.
Description of main conduit: 1,000 feet long.
Description of distributing reservoirs: Two wooden tanks; capacity, 43,200 gallons each.
Sizes of distributing mains: 6 inches.
Available head: 69 feet (average).
Total length of distributing mains: 6,000 feet.
Number of water-takers: 127.
Consumption of water: 63 gallons per head per day (estimated).
First cost of water-works: $14,000.
Average annual cost of maintenance and repairs: $100.

CLARION—Continued.

Filtering apparatus: Made of broken stone; cleaned once a year.
Number of fire-plugs: 11.
Design and dimensions of pump and water-plunger: Eclipse pump, made by H. D. McKnight, Pittsburgh, Pennsylvania; plunger, 4 inches diameter, 3 strokes per minute; pump-barrel, 4 by 14 inches.
Time pumps are run: 3 days per week.
Description of force-main: 3,300 feet long; 210 pounds pressure perpendicular on pump; height, 525 feet.
Description of water-valves: Brass; 2 inches lift.
Kind of power used: Steam.
Description of boilers: Tubular; 100 pounds pressure; fuel, Erie City coal.
Description of engine: Simple; 9 inches diameter, 14 inches stroke, 30 strokes per minute; expansion valves.
Cost of engine and pump: $600.
Duty of engine: 2,700 gallons daily.

HARRISBURG:

Population: 30,762 inhabitants.
Name of corporation: Harrisburg Water-Works (municipal).
Water obtained from: Susquehanna river.
Water first introduced: In 1840.
Discharging capacity: 65 pounds pressure (average).
Description of distributing reservoir: Rectangular embankment, 525 by 275 feet at top, 28 feet deep; slope 1½ to 1; two divisions separated by masonry, dividing wall 14 feet high; slope, 1½ to 1; slopes puddled with concrete, stone, riprap; capacity, 20,000,000 gallons; stand-pipe wrought iron, 5 by 207 feet, brick tower, stone base; situated at pump-station on river.
Sizes of distributing mains: 30, 20, 16, 12, 10, 8, 6, and 4 inches.
Total length of distributing mains: 19.908 miles.
Number of water-takers: 5,000.
First cost of water-works: $600,000.
Average annual cost of maintenance and repairs: $20,000.
Number of fire-plugs: 250.
Design and dimensions of pumps and water-plungers: Two made by Harrisburg Foundery Company, 1874; plain, solid plungers, 22¼ inches diameter, 5 feet stroke, 40 strokes per minute.
Time pumps are run: 14 hours per day.
Description of force-main: 15,220 feet long, 30 inches diameter; cast iron; 90 pounds pressure on pumps.
Description of water-valves: Lifting disk, 7½ inches diameter, 1 inch lift; 28 inches each pump.
Kind of power used: Steam.
Description of boilers: 16 multitubular, 16 feet long, 4 feet diameter; 26 4-inch tubes in each; 100 to 150 pounds pressure; fuel, anthracite coal.
Description of engines: Condensing, 54 inches diameter, 5 feet stroke; non-condensing, 30 inches diameter, 5 feet stroke, 40 strokes per minute; double-beat valves, by cams; jet-condenser, 4 feet long, 24 inches diameter; two air-pumps, 25 inches diameter, 2 feet stroke.
Cost of engines and pumps: $35,000.
Duty of engines: 51,000,000 foot-pounds daily (average).

KENNETT SQUARE:

Population: 1,021 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs.
Total area of water-shed available: About 6 square miles.
Capacity of reservoirs: 100,000 gallons.
Character and dimensions of dam: Covers 2 acres; fed by a race 1 mile long; used to supply pump in case spring should fail.
Cost of dam: $30,000.
Water first introduced: In 1843.
Description of main conduit: ¼ mile long, 6 inches diameter, terra cotta; ½ mile long, 6 inches diameter, iron.

KENNETT SQUARE—Continued.

Description of distributing reservoirs: No. 1, 30 feet square, 10 feet deep; capacity, 66,000 gallons. No. 2, 20 feet square, 10 feet deep; capacity, 34,000 gallons.

Sizes of distributing mains: 6, 4, 3, and 2 inches.

Available head: 10 to 100 feet; water-supply deficient only in extremely dry weather.

Total length of distributing mains: About 1½ mile.

Number of water-takers: About 250.

Consumption of water: 20,000 to 40,000 gallons per day (estimated).

First cost of water-works: $30,000.

Average annual cost of maintenance and repairs: $100 to $200.

Number of fire-plugs: 15.

Design and dimensions of pump and water-plunger: One double-acting, made by Edge F. Cope & Sons, Westchester, Pennsylvania; plain plunger 6 inches diameter, 12 inches stroke, 20 to 30 strokes per minute; pump-barrel, 6 by 12 inches.

Time pump is run: Constantly.

Time spent in repairs: 3 days per year.

Description of force-main: ½ mile long, 6 inches diameter; head, 85 feet on pump.

Description of water-valves: Brass; 6 inches square, on hinges; 4 inches lift.

Kind of power used: Water.

Description of water-wheel: 12 feet diameter; buckets, 4 feet long, made by E. F. Cope & Sons, Westchester, Pennsylvania; 18 feet head, 10 to 18 revolutions per minute; about 12 gallons of water required to lift 1 gallon to reservoir.

KITTANNING:

Population: 2,624 inhabitants.

Name of corporation: Kittanning Water Company (private).

Water obtained from: Allegheny river.

Water first introduced: January, 1872.

Description of distributing reservoir: Clay formation; concrete bottom, with puddled clay; 64 feet square at bottom, 110 feet square at top, 18 feet high; capacity, 1,200,000 gallons.

Sizes of distributing mains: 10, 8, and 4 inches.

Available head: 216 feet; 80 pounds (average).

Total length of distributing mains: 5½ miles.

Number of water-takers: 440.

Consumption of water: 40 gallons per head per day (estimated).

Number of fire-plugs: 26.

Design and dimensions of pump and water-plunger: Made by Epping & Carpenter, Pittsburgh, in 1875; one plain plunger, 10 inches diameter, 2 feet stroke, 28 to 30 strokes per minute; pump-barrel, 10 inches diameter.

Time pump is run: 10 hours per day.

Description of force-main: 2,300 feet long; 120 pounds pressure on pump.

Description of water-valves: 3½ by 12 inches diameter, ¾ inch lift.

Kind of power used: Steam.

Description of boilers: Flue, 22 feet long, 38 inches diameter; 90 pounds pressure; fuel, bituminous coal.

Description of engine: Simple, non-condensing, 16 inches diameter, 2 feet stroke, 28 to 30 strokes per minute; slide-valves, operated with cams.

Cost of engine and pump: $3,500.

LANCASTER:

Population: 25,769 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Conestoga river.

Capacity of reservoirs: No. 1—2,500,000 gallons; No. 2—3,500,000 gallons.

Character and dimensions of dam: 160 feet long, 7 feet high; crib-work and stone.

Water first introduced: In 1836.

Description of distributing reservoir: Embankment, 25 feet wide, lined with brick.

Sizes of distributing main: 20, 12, 10, 8, 6, and 4 inches.

LANCASTER—Continued.

Available head: 1 to 40 feet; water-supply sometimes deficient.

Total length of distributing mains: About 33 miles.

Number of water-takers: About 3,500.

Consumption of water: 112 gallons per head per day (estimated).

First cost of water-works: $442,000.

Average annual cost of maintenance and repairs: About $10,000.

Filtering system: Gallery required, as it is necessary to distribute the muddy water as soon as pumped into the reservoir.

Number of fire-plugs: 350.

Design and dimensions of pumps and water-plungers: Steam, made by Worthington, New York, 1878; 2 water-power, by Berkenbine, and one by Geyelin, in 1869; 3 plain Berkenbine plungers; 10 inches diameter, 44 inches stroke, 23 strokes per minute; one Geyelin plunger, 10 inches diameter, 48 inches stroke, 13 strokes per minute; pump-barrels same size as plungers.

Time pumps are run: Steam, almost constantly; water, very seldom.

Description of force-main: 24, 12, 8, and 3 inches diameter.

Description of water-valves: Gum; 6 inches diameter, 3 inches lift.

Kind of power used: Steam and water.

Description of water-wheels: three 6-foot turbines; Berkenbine, 7 feet head, 23 revolutions per minute; Geyelin, 13 revolutions per minute.

Description of boilers: Four horse-power, tubular; 65 pounds pressure; fuel used, coal No. 1, hard pea.

Description of engine: Compound condensing; 56 strokes per minute; Worthington patent valves and condenser.

Cost of engine and pumps: Worthington, $20,000.

MEADVILLE:

Population: 8,860 inhabitants.

Name of corporation: Meadville Water Company (private).

Water obtained from: French creek.

Capacity of reservoir: 5,000,000 gallons.

Cost of dam: $22,500.

Water first introduced: September, 1875.

Description of main conduit: 160 feet long, 20 inches diameter; 4,750 feet long, 12 inches diameter; cast iron; head, 290 feet (average).

Description of distributing reservoir: 145 by 280 feet; 24 feet deep; division-wall, 12 feet high; walls, puddled clay bricked in cement.

Sizes of distributing mains: 12, 6, and 4 inches.

Available head: 250 feet (average).

Total length of distributing mains: 13¼ miles.

Number of water-takers: 700.

Consumption of water: 280,000 gallons per day.

First cost of water-works: $137,735.

Average annual cost of maintenance and repairs: $3,000.

Filtering system: 34 by 35 feet; filled with gravel; cleaned every 3 years.

Number of fire-plugs: 89.

Design and dimensions of pumps and water-plungers: One Flander's improved; one W. H. Lang; one Flander's; two plain Flander's plungers, 10 inches diameter, 20 inches stroke; Flander's improved plunger, 12 inches diameter, 30 inches stroke, 14 to 20 strokes per minute; pump-barrels, 12½ inches diameter.

Time pumps are run: Flander's, 10 hours per day.

Description of force-main: 4,500 feet long; 120 pounds pressure on pumps.

Description of water-valves: Lang's and Flander's.

Kind of power used: Water.

Description of water-wheel: One, turbine, 54 inches diameter, 15 feet head.

MOUNT JOY:

Population: 2,058 inhabitants.

Style of corporation: Municipal.

Water obtained from: Chiques Salunga creek.

MOUNT JOY—Continued.

Total area of water-shed available: 48 square miles.
Character and dimensions of dam: 80 feet wide, 5 feet fall; backing up about 1,800 feet; walled up with stone.
Cost of dam: $40,000.
Water first introduced: In 1874.
Description of main conduit: 8 inches diameter; cast iron.
Description of distributing reservoir: Capacity, 750,000 gallons; 126 feet above creek; water pumped up 86 feet above main level of town; made by excavation and embankment, lined with puddled clay and brick, 13 feet deep.
Sizes of distributing mains: 8, 6, and 4 inches.
Total length of distributing mains: 17,344 feet.
Number of water-takers: 159.
First cost of water-works: $40,000.
Average annual cost of maintenance and repairs: $500.
Number of fire-plugs: 25.
Design and dimensions of pump and water-plunger: Made by Weiner & Berkenbine, Lebanon, Pennsylvania; plain plunger, with patent water-cushions; 6 inches diameter, 2 feet stroke, 40 strokes per minute.
Time pump is run: 3 to 4 days per week.
Description of force-main: 1,000 feet long; 50 pounds pressure on pump.
Description of water-valves: Brass; 8 inches diameter, ½ inch lift.
Kind of power used: Steam and water.
Description of water-wheel: Riston turbine; 6 feet head.
Description of boiler: 13 feet long, 3½ feet diameter; 50 to 70 pounds pressure; fuel used, soft nut coal.
Description of engine: Simple; 10 inches diameter, 18 inches stroke, 110 strokes per minute; four air-chambers, 12 inches diameter, 2 feet high.
Remarks: No impurities, except in rainy weather, when water is muddy.

NORRISTOWN:

Population: 13,063 inhabitants.
Name of corporation: The Norristown Insurance and Water Company (private).
Water obtained from: Schuylkill river.
Water first introduced: December, 1847.
Description of distributing reservoirs: One, capacity about 1,000,000 gallons; one, capacity about 10,000,000 gallons; partly excavated and partly embankment; puddled with clay and paved with bricks.
Sizes of distributing mains: 16, 12, 10, 8, 6, 4, and 3 inches.
Available head: 1st reservoir, 132 feet (average); 2d reservoir, 194 feet (average); water-supply seldom deficient.
Total length of distributing mains: 10 to 15 miles.
Number of water-takers: 2,500 to 3,000.
Consumption of water: 750,000 gallons per day (estimated).
Number of fire-plugs: 150.
Design and dimensions of pumps and water-plungers: No. 1, made by H. R. Worthington, New York; plunger, two 14-inch pistons, brass packing, 20 strokes per minute; pump-barrel, 14 by 18 inches; No. 2, made by R. S. Newbold, Norristown, Pennsylvania; one 16-inch plunger, 13 strokes per minute; pump-barrel, 16 by 60 inches; both plungers double.
Description of force-main: 1⅓ mile long, 24 inches diameter; 1st reservoir, 57 pounds pressure on pumps; 2d reservoir, 80 pounds pressure.
Description of water-valves: No. 1, rubber; No. 2, metal, leather faced.
Kind of power used: Steam.
Description of boilers: Six, 30 inches by 33 feet, plain cylinder or tubular boiler, equal to 3 of the above.
Description of engines: No. 1, compound; high-pressure cylinder 16 inches diameter, low-pressure cylinder 24 inches diameter, 18 inches stroke, 80 strokes per minute; No. 2, non-condensing, 32 inches high, 5 feet stroke, 26 strokes per minute; ordinary globe valves, by hand; 4 single 8 by 12 inches cylinder condenser.

OIL CITY

Population: 7,315 inhabitants.
Name of corporation: Oil City Water Company (municipal).
Water obtained from: Allegheny river.
Capacity of reservoir: 3,000,000 gallons.
Cost of dam: About $160,000.
Water first introduced: In 1872.
Description of main conduit: 12 inches diameter; iron; head, 310 feet.
Description of distributing reservoir: Excavated; two compartments, 80 by 80 feet, with berme 10 feet high; slope, 1½ to 1; total depth, 20 feet; puddled with clay and lined with brick.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 80 to 120 pounds.
Total length of distributing mains: 10 miles.
Number of water-takers: About 1,000.
Consumption of water: 560,000 gallons per day or 70 gallons per head (estimated).
First cost of water-works: $160,000.
Average annual cost of maintenance and repairs: About $6,000.
Number of fire-plugs: 72.
Design and dimensions of pump and water-plunger: Made by Eclipse Pump Works, Pittsburgh, Pennsylvania, in 1872; plain plunger, 20 by 30 inches cylinder, 14 to 20 strokes per minute; pump-barrel, 12 inches diameter.
Time pump is run: 24 hours; one at a time.
Description of force-main: 1,200 feet long and 310 feet long; 130 pounds pressure on pumps.
Description of water-valves: Metal, lined with leather; 4½ by 9 inches diameter.
Kind of power used: Steam.
Description of boilers: Two; 5 by 12 feet; 62 3-inch flues; fuel, bituminous coal.
Description of engine: Simple cylinder, 2 feet diameter, 2 feet 6 inches stroke, 14 to 20 strokes per minute; round valves worked by cam-brake from cylinder.
Cost of engine and pump: $4,000.
Duty of engine: 560,000 gallons daily.
Remarks: Water is impure only in June from vegetable matter.

OXFORD:

Population: 1,502 inhabitants.
Style of corporation: Municipal.
Water obtained from: Wells.
Capacity of reservoir: 48,500 cubic feet.
Water first introduced: In 1870.
Description of main conduit: 7,260 feet long, 6 inches diameter; 6,456 feet long, 4 inches diameter; 4,689 feet long, 3 inches diameter; cast iron.
Description of distributing reservoir: 80 by 80 feet, top; 24 by 24 feet, bottom; 18 feet deep; basin lined with puddle clay and paved with bricks.
Sizes of distributing mains: 6 and 4 inches.
Available head: About 20 feet (average); water-supply sometimes deficient.
Total length of distributing mains: About 13,716 feet.
Number of water-takers: About 110.
First cost of water-works: About $40,000.
Average annual cost of maintenance and repairs: About $600.
Number of fire-plugs: 18.
Design and dimensions of pumps and water-plungers: Two; 4 plain plungers, 4 inches diameter, 2 feet stroke, 8 or 10 strokes per minute; diameter of pump-barrel, 4 inches.
Description of force-main: 4,689 feet long, 3 inches diameter.
Description of water-valves: Brass.
Kind of power used: Steam and water.
Description of water-wheel: Overshot; 11 feet diameter, 3 feet lift, 11 feet head, 8 to 10 revolutions per minute.
Description of boilers: About 4 horse-power; fuel used, anthracite coal.
Description of engine: Simple.
Duty of engine: About 20,000 gallons daily.

PARKER'S LANDING:

Population: 1,835 inhabitants.
Name of corporation: Parker's and Lawrenceburg Water Company (private).
Water obtained from: Allegheny river.
Area and capacity of reservoirs: 48,000 gallons each at three points.
Water first introduced: In 1872.
Description of main conduit: 4 inches diameter; head, 50 to 150 feet.
Description of distributing reservoirs: Wooden tankage at three points.
Size of distributing mains: 4 inches.
Available head: 40 to 80 pounds.
Total length of distributing mains: About 2 miles.
Number of water-takers: 200.
Consumption of water: 8,000 gallons per day (estimated).
First cost of water-works: $14,000.
Average annual cost of maintenance and repairs: $300.
Filtering apparatus: Tank, 8 by 12 by 5 feet, sunk in bottom of river, filled with sand and gravel.
Number of fire-plugs: 37.
Design and dimensions of pumps and water-plungers: Cameron pumps; made in 1881; 2 plain plungers; 6 inches diameter; 12 inches stroke; 35 strokes per minute; pump-barrel, 6 by 12 inches.
Time pumps are run: About 20 hours per day.
Description of force-main: ⅞ mile long; 200 pounds pressure on pumps.
Description of water-valves: Flat composition.
Kind of power used: Steam.
Description of boiler: Tubular; 40 horse-power; 75 pounds pressure; fuel, bituminous coal.
Description of engine: Non-condensing; 14 inches diameter, 12 inches stroke, 40 strokes per minute; simple globe-valves.
Cost of engine and pumps: $600 each.

PHŒNIXVILLE:

Population: 6,682 inhabitants.
Style of corporation: Municipal.
Water obtained from: Schuylkill river.
Total area of water-shed available: 80 square miles.
Capacity of reservoir: 2,250,000 gallons.
Character and dimensions of dams: Receive water from Black Rock dam; 2 miles long, ⅛ mile wide.
Cost of dam: $201,000.
Water first introduced: In 1873.
Description of main conduit: 1 mile long, 16 inches diameter; cast iron; 60 to 72 pounds pressure.
Description of distributing reservoir: 190 feet above level of river; lined inside, 18 inches clay; covered with brick and cement; division-wall, 6 feet high; depth of water, 11 feet.
Sizes of distributing mains: 16, 12, 10, 8, 6, and 4 inches.
Available head: 65 pounds (average).
Total length of distributing mains: About 12 miles.
Number of water-takers: 453.
Consumption of water: 450,000 gallons per day, or 64 gallons per head (exact).
First cost of water-works: $195,000.
Average annual cost of maintenance and repairs: $3,000; $14,000 bonded debt.
Number of fire-plugs: 126.
Design and dimensions of pump and water-plungers: Compound duplex, made by Worthington, New York; two plain plungers, 12 and 14 inches diameter, 24 inches stroke each, 24 strokes per minute; one 12- and one 14-inch pump-barrel.
Time pump is run: 10 hours per day (average).
Time spent in repairs: 10 days in a year (average).
Description of force-main: 900 feet long.
Description of water-valves: Rubber; 6 inches diameter, ¾ inch lift.
Kind of power used: Steam.
Description of boilers: Tubular, 5 by 14 feet; fuel, pea coal.

PHŒNIXVILLE—Continued.

Description of engine: Compound duplex condensing; high-pressure cylinder 23 inches diameter, low-pressure cylinder 36 inches diameter, 24 inches stroke, 15 strokes per minute; common globe-valves; double 15-inch bore air-pump, 12 inches stroke.
Duty of engine: 37,000,000 foot-pounds.
Remarks: The American Wood Paper Company's works are 2½ miles above water-works on river, and refuse and chemicals used in dyeing contaminate the water.

PITTSTON:

Population: 7,472 inhabitants.
Name of corporation: Pittston Water Company (private).
Water obtained from: Susquehanna river.
Water first introduced: In 1856.
Description of distributing reservoir: Area, top, 129½ feet long, 106½ feet wide; bottom, 69½ feet long, 46½ feet wide; depth of water, 15 feet; capacity, 1,000,000 gallons.
Sizes of distributing mains: 12, 8, 6, 4, 3, and 2 inches.
Available head: 40 to 50 pounds.
Number of water-takers: 1,660.
Consumption of water: 50,000 gallons per day, or 70 gallons per head per day (estimated).
Average annual cost of maintenance and repairs: $7,839.
Number of fire-plugs: 38.
Design and dimensions of pump and water-plungers: Made by H. R. Worthington, New York, in 1877; 4 plungers, 16 inches diameter, 20½ inches stroke, 15 strokes per minute; pump-barrel, 20 by 24 inches.
Time pump is run: 10 hours per day (average).
Time spent in repairs: About 36 hours per year.
Description of force-main: 85 pounds pressure on pump.
Description of water-valves: Rubber; 6 inches diameter.
Kind of power used: Steam.
Description of boilers: Six plain cylinder; 36 feet long, 30 inches diameter; 75 pounds pressure; fuel used, culm.
Description of engine: Compound condensing; high-pressure cylinder 21¾ inches diameter, low-pressure cylinder 34½ inches diameter, 20½ inches stroke, 15 strokes per minute; Worthington, duplex valves.
Cost of engine and pump: $7,500.
Duty of engine: 750,000 gallons daily; 2,000,000 gallons per day guaranteed.

SAINT PETERSBURG:

Population: 1,044 inhabitants.
Name of corporation: Saint Petersburg Water-Works (municipal).
Water obtained from: Spring.
Water first introduced: April, 1873.
Description of distributing reservoirs: Two wooden tanks; capacity, 39,600 gallons each.
Sizes of distributing mains: 4, 3, and 2 inches.
Available head: About 40 pounds (average).
Total length of distributing mains: 2 miles.
Number of water-takers: 125.
Consumption of water: 15,750 gallons per day (estimated).
First cost of water-works: $10,000.
Average annual cost of maintenance and repairs: $1,000.
Number of fire-plugs: 10.
Design and dimensions of pump and water-plunger: One Cameron pump, plain plunger; diameter of pump-barrel, 4 inches.
Time pump is run: 8 to 10 hours per day.
Description of force-main: 700 feet long, 2.2 inches diameter.
Kind of power used: Steam.
Description of boiler: One 15 horse-power (Tift); 40 pounds pressure; fuel, bituminous coal.
Cost of engine: $400.

SUMMIT HILL:

Population: 788 inhabitants.
Name of corporation: Summit Hill Water Company (private).
Water obtained from: Mountain streams.

SUMMITT HILL—Continued.

Total area of water-shed available: 2 square miles.
Capacity of reservoir: 24,000 cubic feet.
Cost of dam: $2,400.
Water first introduced: January, 1877.
Discharging capacity: 40 to 75 feet head.
Description of distributing reservoir: 100 feet long, 30 feet wide, 8 feet overflow.
Sizes of distributing mains: 8, 6, 4, and 3 inches.
Available head: 40 to 75 feet.
Total length of distributing mains: 7,000 feet.
Number of water-takers: 350.
Consumption of water: 15,000 gallons per day (estimated).
First cost of water-works: $12,000.
Average annual cost of maintenance and repairs: $720.
Number of fire-plugs: 13.
Design and dimensions of pump and water-plungers: Made by Carter & Allen, Tamaqua, Pennsylvania, in 1876; two plain plungers, 4 inches diameter, 18 inches stroke, 25 strokes per minute; pump-barrel, 4 inches diameter.
Time pump is run: About 5 hours per day.
Description of force-main: 5,700 feet long, 12 inches diameter; 130 pounds pressure on pumps.
Description of water-valves: Steam-valves.
Kind of power used: Steam.
Description of boilers: Upright tubular, 9 feet high, 48 inches diameter, 45 pounds pressure; fuel, anthracite coal.
Description of engine: Non-condensing, double; 12 inches diameter, 18 inches stroke, 25 strokes per minute; ordinary cut-off valves.
Cost of engine and pump: $2,300.
Duty of engine: 2,304,000 foot-pounds daily.

WESTCHESTER:

Population: 7,046 inhabitants.
Style of corporation: Municipal.
Water obtained from: Small creek.
Area and capacity of reservoir: 22,500 square feet; nearly 2,000,000 gallons.
Character and dimensions of dam: Very small one; pool, 200 by 100 feet, used for collecting and holding water; depth, 6 feet (average).
Cost of dam: Reservoir (proposed), $12,000.
Water first introduced: In 1840.
Description of main conduit: 1½ mile long, 12 inches diameter; iron; head, 40 feet.
Description of distributing reservoir: 160 by 140 feet; has a division about 6 feet from bottom, making two sections; side sloped 30°; embankments rise 7 feet above ground, bottom 7 feet below ground; lined with clay and paved with brick.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 40 to 100 feet.
Total length of distributing mains: 9 to 10 miles.
Number of water-takers: About 1,400.
Consumption of water: 250,000 gallons per day.
Average annual cost of maintenance and repairs: About $4,000.
Number of fire-plugs: 130.
Design and dimensions of pump and water-plunger: Pump-barrel, 7 inches diameter.
Time pump is run: 10 to 16 hours per day.
Kind of power used: Steam.

YORK:

Population: 13,940 inhabitants.
Style of corporation: Private.
Description of distributing reservoir: 200 by 300 feet, 11 feet deep.
Sizes of distributing mains: 10 to 2 inches.
Available head: 11 to 60 feet; water-supply deficient.
Total length of distributing mains: 13 miles.
Number of water-takers: 2,800.
Consumption of water: 273,600 gallons per day (estimated).

YORK—Continued.

Filtering apparatus: Cleaned every 5 years.
Design and dimensions of pump and water-plunger: Made by Berkenbine, Philadelphia, Pennsylvania, in 1850; round brass-ring plunger, 10 inches diameter, 36 inches stroke, 19 strokes per minute; pump-barrel, 10 inches diameter, 36 inches stroke.
Time pump is run: Constantly.
Description of force-main: 3,300 feet long, 90 feet rise, 10 inches diameter.
Description of water-valves: 8½ to 10½ inches.
Kind of power used: Steam.
Description of boilers: Return tubular; 60 pounds pressure; evaporated 3,000 gallons in 12 hours; fuel, anthracite coal.
Description of engine: Condenser, 10 inches diameter, 3 feet stroke, 56 strokes per minute; common valves.
Cost of engine and pump: $2,500.

TENNESSEE.

CHATTANOOGA:

Population: 12,892 inhabitants.
Name of corporation: Lookout Water Company (private).
Water obtained from: Tennessee river.
Cost of dams: $16,000.
Water first introduced: In 1869.
Description of main conduit: 12 inches diameter; iron.
Description of distributing reservoir: In two divisions; can discharge into either from pump, or supply city with either.
Sizes of distributing mains: 12 to 1½ inches.
Available head: 125 feet (average).
Total length of distributing mains: About 12 miles.
Number of water-takers: About 700.
Consumption of water: 1,250,000 gallons per day (estimated).
First cost of water-works: $115,000.
Average annual cost of maintenance and repairs: $16,050.
Number of fire-plugs: 58.
Design and dimensions of pump and water-plungers: Made by G. M. Woodward, New York, in 1869; plain double-acting plungers; two, 20 by 8 inches; two, 16 by 8 inches; one, 16 by 8 inches; 30 strokes per minute; pump-barrels, 12 and 9 inches diameter.
Time pumps is run: 20 hours per day.
Description of force-main: 800 feet long; 158 feet head on pump.
Description of water-valves: Metal.
Kind of power used: Steam.
Description of boilers: 22 feet long, 44 inches diameter; 4 flues, two 12 inches and two 29 inches diameter; 50 pounds pressure; fuel, soft coal.
Description of engines: Simple, high pressure; 16 and 20 inches diameter, 8 inches stroke, 30 and 50 strokes per minute; slide and eccentric valves.
Cost of engines and pump: $6,000.
Duty of engine: 3,828,125 foot-pounds daily.

TEXAS.

AUSTIN:

Population: 11,013 inhabitants.
Name of corporation: City Water Company (private).
Water obtained from: Colorado river.
Cost of dam: $10,000.
Water first introduced: February, 1876.
Description of distributing reservoir: 14,240 feet from pumps; covers 1 acre; capacity, 2,500,000 gallons; slopes are lined with concrete, 6 inches thick; elevation, 170 feet above pumps.
Sizes of distributing mains: 10, 8, and 6 inches.
Available head: 60 pounds (average).
Total length of distributing mains: About 10 miles.
Number of water-takers: 525.
Consumption of water: 227,309 gallons per day (exact).

AUSTIN—Continued.

First cost of water-works: $80,000.
Average annual cost of maintenance and repairs: $13,000.
Number of fire-plugs: 75.
Design and dimensions of pumps and water-plungers: Two, made by Blake & Co., Boston, Massachusetts, in 1875; bucket-plungers, 65 strokes per minute; pump-cylinder, 14 by 24 inches.
Time pumps are run: 2,207 hours per year.
Description of force-main: 14,240 feet long; 80 pounds pressure on pumps.
Description of water-valves: Rubber; 5 inches diameter.
Kind of power used: Steam.
Description of boilers: Two; flue; 14 feet long, 48 inches diameter, 55 pounds pressure.
Description of engine: Cylinder, 20 inches diameter, 24 inches stroke, 65 strokes per minute; Ludlow valves.
Duty of engines: 2,437,500 foot-pounds daily.

VERMONT.

BURLINGTON:

Population: 11,365 inhabitants.
Name of corporation: Burlington Water-Works (municipal).
Water obtained from: Lake Champlain.
Water first introduced: In 1866.
Discharging capacity: Head, 284 feet (average).
Description of distributing reservoir: Embankment; capacity, 3,000,000 to 4,000,000 gallons.
Sizes of distributing mains: 10, 6, 4, and 3 inches.
Total length of distributing mains: 25 miles.
Number of water-takers: 2,200.
Consumption of water: 600,000 gallons per day.
First cost of water-works: $450,000.
Average annual cost of maintenance and repairs: $6,443.
Number of fire-plugs: 138.
Design and dimensions of pumps and water-plungers: Two; made by H. R. Worthington, New York, in 1866; plain plungers, 10 inches diameter, 17 inches stroke, 21½ strokes per minute.
Time pumps are run: 10 hours per day.
Description of force-main: 1¾ mile long, 10 inches diameter.
Description of water-valves: 9 inlet and 9 discharge each cylinder; 3 inches diameter, ½ inch lift.
Kind of power used: Steam.

BURLINGTON—Continued.

Description of boilers: Two multitubular, 14 feet long, 3½ feet diameter; 44 tubes, 3 inches diameter each; 40 pounds pressure; fuel, anthracite coal.
Description of engine: Compound; high-pressure cylinder 14 inches diameter, low-pressure cylinder 24½ inches diameter, 17 inches stroke, 21½ strokes per minute each; slide-valves; condenser, 14 by 48 inches; air-pump, 9 by 17 inches.
Cost of pumps and engine: $10,600.
Remarks: Whole pumping plants in bad condition.

VIRGINIA.

DANVILLE:

Population: 7,526 inhabitants.
Name of corporation: Danville Water and Gas Works (municipal).
Water obtained from: Dan river.
Capacity of reservoir: 1,500,000 gallons.
Water first introduced: In 1875.
Description of distributing reservoir: 165 by 155 feet top, 15 feet deep; slope 2 to 1; made of loose earth, embankments lined with brick.
Sizes of distributing mains: 10, 8, 6, 4, and 3 inches.
Available head: 19 to 180 feet.
Total length of distributing mains: 8.2 miles.
Number of water-takers: 306.
First cost of water-works: $141,500.
Average annual cost of maintenance and repairs: $6,475 68 in 1880.
Number of fire-plugs: 66.
Design and dimensions of pump and water-plungers: Made by H. R. Worthington, New York, in 1875; two plain plungers, 18 inches diameter, 12 inches stroke, 100 to 200 strokes per minute.
Description of force-main: 3,600 feet long; 80 pounds pressure on pump.
Description of water-valves: Gum; 2 inches diameter.
Kind of power used: Steam.
Description of boilers: Tubular; 15 feet long, 5 feet diameter; 52 flues; 65 pounds pressure; fuel, wood.
Description of engine: Non-condensing; 20 inches diameter, 12 inches stroke, 100 to 180 strokes per minute.
Duty of engine: 1,000,000 foot-pounds daily.

WATER-WORKS EMPLOYING SYSTEM OF PUMPING TO STAND-PIPE.

ARKANSAS.

LITTLE ROCK:

Population: 13,138 inhabitants.
Name of corporation: Little Rock Water Company (private).
Water obtained from: Arkansas river; about to use well in soil, near river, ½ mile above court-house; rest, drive-wells.
Water first introduced: In 1878.
Description of stand-pipe: 100 feet high, 20 feet diameter; wrought iron; one outlet and one inlet; used as surplus over direct pumping; filled at night.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Total length of distributing mains: 5 miles.
Number of water-takers: 300.
Consumption of water: About 200,000 gallons per day.
First cost of water-works: Contract was for $100,000.
Average annual cost of maintenance and repairs: $3,000.
Number of fire-plugs: 100.
Design and dimensions of pumps and water-plungers: Two, double-acting, made by George F. Blake, New York, in 1878; piston-plunger, 14 inches diameter, 24 inches stroke; varies up to 45 double strokes per minute; pressure on pumps, about 62 pounds.
Time pumps are run: One or the other 8 to 10 hours per day.
Description of force-main: About 300 feet long, 12 inches diameter.
Description of water-valves: Brass disks; 24 inlet and 24 discharge; 3 inches diameter; maximum lift, ⅜ inch.
Kind of power used: Steam.
Description of boilers: Two, cylindrical; 20 feet long, 48 inches diameter; 12 tubes, 5½ inches diameter, in each; 80 to 130 pounds pressure.
Fuel: Pittsburgh coal.
Description of engine: High-pressure condensing; cylinder, 30 inches diameter, 24 inches stroke, up to 45 double strokes per minute; slide-valves by piston-valve rod; Berkeley condenser.
Duty of engine: 1,000,000 gallons daily.

GEORGIA.

AUGUSTA:

Population: 21,891 inhabitants.
Name of corporation: Augusta Water-Works (municipal).
Water obtained from: Savannah river by Augusta canal.
Character and dimensions of dam: 1,700 feet long, 9 feet deep (average), 6 feet wide, top; upstream fall 15 inches lower than downstream; rubble masonry.
Cost of dam: $30,000.
Water first introduced: In 1861.
Description of main conduit: 345.5 feet long, 20 inches diameter; cast iron.
Discharging capacity: 9.33 cubic feet per second; head, 17 feet (average).
Description of stand-pipe: Two concentric brick towers 68 feet high, supporting a boiler-iron tank 37 feet diameter and 30 feet deep.
Sizes of distributing mains: 6 and 4 inches.
Available head: 25 to 32 pounds; water-supply deficient.
Total length of distributing mains: 21.61 miles.

AUGUSTA—Continued.

Number of water-takers: 1,644.
Consumption of water: 81.5 gallons per head per day (estimated).
Average annual cost of maintenance and repairs: $7,342 78.
Filtering apparatus: Three settling basins; bricks set on edge; capacity, 18,000,000 gallons.
Number of fire-plugs: 163.
Design and dimensions of pump and water-plungers: Made by I. P. Morris & Co., Philadelphia, Pennsylvania, in 1860; two bucket-plungers, 18¼ inches diameter, 3 feet stroke, 20 strokes per minute; pump-barrel, 3 feet by 18¼ inches.
Time pump is run: Constantly.
Time spent in repairs: 24 hours per year.
Description of force-main: 2,490 feet long, 16 inches diameter, 38.12 pounds pressure; 88 feet head on pump.
Kind of power used: Water and steam.
Description of water-wheel: Jonval turbine, 45 horse-power, 11 feet head, 66 revolutions per minute.
Description of boiler: 15 feet long, 4 feet diameter; 63 flues, 3 inches diameter.
Description of engines: Steam, simple, 20 inches diameter, 24 inches stroke; water, 14 inches diameter, 24 inches stroke, 65 strokes per minute.

SAVANNAH:

Population: 30,709 inhabitants.
Name of corporation: Savannah Water-Works (municipal).
Water obtained from: Savannah river.
Water first introduced: In 1854.
Description of stand-pipe: Brick tower, 50 feet high, 12-inch iron beams on top support a tank of boiler-iron 30 feet diameter and 57 feet high.
Sizes of distributing mains: 12, 6, and 4 inches.
Available head: About 40 pounds (average); water-supply deficient, because mains are too small.
Total length of distributing mains: 22 miles.
Number of water-takers; 2,013.
Consumption of water: 75 gallons per head per day.
First cost of water-works: $225,000.
Average annual cost of maintenance and repairs: $11,000.
Number of fire-plugs: 257.
Design and dimensions of pumps and water-plungers: Made by Worthington, one in 1854, and one duplex in 1874; plain plungers, 17¾ inches diameter, 3 feet stroke, about 40 strokes per minute.
Time pumps are run: Constantly.
Description of force-mains: Two, each 3,000 feet long, 16 and 12 inches diameter; 56 pounds pressure on pumps.
Description of water-valves: India-rubber; 7 inches diameter, ½ inch lift.
Kind of power used: Steam.
Description of boilers: Return tubular; 14 feet long, 48 inches diameter; 40 pounds pressure; fuel, wood.
Description of engine: Compound condensing; high-pressure cylinder, 21 inches diameter, 3 feet stroke; expansion cylinder, 36 inches diameter, 3 feet stroke, 40 strokes per minute; common D valve.
Cost of pumps and engine: $25,000.
Duty of engine: 45,000,000 foot-pounds daily.
Remarks: Water discolored during freshet by red clay.

INDIANA.

SOUTH BEND:

Population: 13,280 inhabitants.
Style of corporation: Municipal.
Water obtained from: Saint Joseph river.
Character and dimensions of dam: 600 feet long, 9 feet fall; made of wood
Cost of dam: $100,000.
Water first introduced: In 1873.
Description of stand-pipe: 204 feet high, 5 feet diameter.
Sizes of distributing mains: 20, 16, 12, 10, 8, and 6 inches.
Available head: 150 feet.
Total length of distributing mains: 16 miles.
Number of water-takers: 500.
First cost of water-works: $170,000.
Average annual cost of maintenance and repairs: About $3,000.
Number of fire-plugs: 200.
Design and dimensions of pump and water-plungers: Made by Flanders & Co., Vergennes, Vermont; plain plungers, 14 by 20 inches, 6 double-acting, taking and discharging water at each end of cylinder; 20 strokes per minute; pump-barrel, 14 inches diameter.
Time pump is run: Constantly.
Time spent in repairs: 48 hours per year.
Description of force-main: 300 feet long, 150 feet head on pump.
Description of water-valves: Iron, with rubber and brass; rubber removable, and brass on seats; 10 inches diameter, 1 foot lift.
Kind of power used: Water.
Description of water-wheels: Three 66-inch American turbines, made by Stout, Mills, & Temple, Dayton, Ohio; 7 to 9 feet head; 16 revolutions per minute.
Cost of engine and pump: $4,000.

TERRE HAUTE:

Population: 26,042 inhabitants.
Name of corporation: Terre Haute Water-Works Company (private).
Water obtained from: Wabash river.
Description of stand-pipe: Each pump has a close stand-pipe 28 feet high, 24 inches diameter, into which all the water is pumped; from thence, by compressed air, it is forced into the mains.
Sizes of distributing mains: 16, 12, 10, 8, 6, and 4 inches.
Available head: 40 pounds (average).
Total length of distributing mains: $17\frac{4361}{5280}$ miles.
Number of water-takers: 453.
Consumption of water: 900,000 gallons per day (estimated).
First cost of water-works: $300,951.
Average annual cost of maintenance and repairs: $6,500.
Filtering apparatus: Coarse gravel in gallery; cleaned twice per year.
Number of fire-plugs: 374.
Design and dimensions of pump and water-plungers: Made by Clapp & Jones, Hudson, New York, in 1873; 4 grooved plungers, 9 inches diameter, 36 inches stroke, 6 to 60 strokes per minute; pump-barrel, 9 by 36 inches.
Time pump is run: Constantly.
Description of force-main: 16 inches diameter; 40 pounds pressure on pump.
Description of water-valves: Clapp's, patent rubber; 1 inch thick, 4 inches wide.
Kind of power used: Steam.
Description of boilers: Two; 16 feet long, 44 inches diameter; two 16-inch flues each; 1 Babcock & Wilcox, 75 horse-power; fuel, slack coal.
Description of engines: Four condensing beam, 20 inches diameter, 36 inches stroke, 6 to 60 double strokes per minute; common slide cut-off; air-pump, 10 by 15 inches; jet-condenser.
Cost of engines and pump: $45,000.
Duty of engines: 45,000,000 foot-pounds daily (average).

MASSACHUSETTS.

FALL RIVER:

Population: 48,961 inhabitants.
Name of corporation: Fall River Water-Works (municipal).
Water obtained from: Watuppa lakes.
Total area of water-shed available: $31\frac{1}{4}$ square miles.
Water first introduced: In 1874.
Description of main conduit: 87 feet long; cross-section, 6 feet wide; to crown of each inside radius, 3 feet; brick.
Description of stand-pipes: One 80 feet high, the other 40 feet high; each 3 feet 6 inches diameter; built of boiler-iron.
Sizes of distributing mains: 24 to 6 inches.
Total length of distributing mains: 52.05 miles.
Number of water-takers: 2,809.
Consumption of water: 27 gallons per head per day (estimated).
First cost of water-works: $1,451,364 52.
Average annual cost of maintenance and repairs: $20,000.
Number of fire-plugs: 537.
Design and dimensions of pumps and water-plungers: One, made by Boston Machine Company, in 1874, two plungers, 16 inches diameter, 48 inches stroke; one, duplex Worthington, 1875, plain plunger, $22\frac{1}{2}$ inches diameter, 48 inches stroke; one, 22 inches diameter, 48 inches stroke, 4 strokes per minute.
Time pumps are run: Constantly.
Time spent in repairs: 19 days in 1880.
Description of force-main: 1,350 feet long; head on low-pressure 151 feet, high-pressure 186 feet (average).
Description of water-valves: Rubber; 6 inches diameter, $\frac{3}{4}$ inch lift.
Kind of power used: Steam.
Description of boilers: Two, return tubular, 6 feet 6 inches by 6 feet long, with 96 tubes, 4 inches diameter each; fuel, Cumberland coal.
Description of engines: Boston, condensing; puppet-valves operated by cams; air-pump, 27 by $29\frac{3}{4}$ inches, 23 inches stroke; 6 feet 6 inches rubber-top valve; condenser, 6 by 3 feet. Worthington compound, 11.6 strokes per minute; balance slide-valves.
Cost of engines and pumps: Boston, $36,760 18; Worthington, $50,371 24.
Duty of engines: Boston, 23,414,336 foot-pounds daily; 60,000,000 foot-pounds guaranteed. Worthington, 49,914,028 foot-pounds daily; 65,000,000 foot-pounds guaranteed.

NANTUCKET:

Population: 3,727 inhabitants.
Name of corporation: Wannacomet Water Company (private).
Water obtained from: Wannacomet lake.
Total area of water-shed available: 25 acres.
Capacity of reservoir: 50,000 gallons.
Cost of dam: $2,500.
Water first introduced: In 1879.
Description of main conduit: 2 miles long, 8 inches diameter; cast iron; 104 feet head (average).
Description of stand-pipe: $\frac{1}{4}$-inch boiler-iron circular tank, 24 feet diameter, 15 feet deep, 42 feet above ground, on iron trestle-work.
Sizes of distributing mains: 6, 4, and 2 inches.
Available head: About 90 feet (average).
Total length of distributing mains: About 5 miles.
Number of water-takers: 150.
Consumption of water: 60,000 gallons per day (estimated).
First cost of water-works: $40,000.
Average annual cost of maintenance and repairs: About $600.
Number of fire-plugs: 4.
Design and dimensions of pumps and water-plungers: One made by H. R. Worthington, New York, in 1880; two plain plungers, 14 inches diameter, 10 inches stroke; one made by G. F. Blake & Co., Boston, in 1878; two plain plungers, 6 inches diameter, 12 inches stroke, 200 strokes per minute.
Time pumps are run: One pump 5 hours per day.
Description of force-main: 400 feet long, 8 inches diameter; 38 pounds pressure on pumps.

NANTUCKET—Continued.

Description of water-valves: Rubber disks.
Kind of power used: Steam.
Description of boilers: One upright tubular, 15 horse-power; 77 tubes, 2 inches diameter, 5 feet long; 60 pounds pressure; one locomotive, 45 horse-power; 83 tubes, 2 inches diameter, 12 feet long; 60 pounds pressure; fuel, hard coal.
Cost of pump and engine: $1,800.

NEW JERSEY.

BELVIDERE:

Population: 1,773 inhabitants.
Name of corporation: Belvidere Water-Works (private).
Water obtained from: Delaware river.
Water first introduced: In 1878.
Description of main conduit: 235 feet long, 10 inches diameter; cast iron; head, 160 feet (average).
Description of stand-pipe: 160 feet high; made of heavy boiler-iron, on stone foundation.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: About 100 feet (average).
Total length of distributing mains: About 15,000 feet.
Number of water-takers: 106.
Consumption of water: 35,000 gallons per day (estimated).
First cost of water-works: About $40,000.
Number of fire-plugs: 15.
Design and dimensions of pump and water-plungers: Blake's duplex pump, made by Blake Manufacturing Company, Boston and New York, in 1878; two plungers, bucket or suction, 8 inches diameter, 12 inches stroke, 100 strokes per minute (average); pump-barrel, 8 inches diameter.
Time pump is run: About 2 hours per day.
Description of force-main: 164 feet long; 80 pounds pressure on pumps.
Description of water-valves: Rubber; 3 inches diameter, inch lift.
Kind of power used: Steam.
Description of boilers: Tubular; 50 pounds pressure (average); fuel, No. 2 chestnut coal.
Description of engine: Simple; 14 inches diameter, 12 inches stroke, 100 strokes per minute (average); Blake's patent valves.
Cost of engine and pumps: About $2,700.
Remarks: Water very pure.

MILLVILLE:

Population: 7,660 inhabitants.
Name of corporation: Millville Water Company (private).
Water obtained from: Well.
Water first introduced: In 1879.
Description of stand-pipe: 128 feet high, 12 feet diameter.
Sizes of distributing mains: 12, 8, 6, 4, and 3 inches.
Available head: 40 pounds (average).
Total length of distributing mains: 41,364 feet.
Number of water-takers: 227.
Consumption of water: 150,000 gallons per day (estimated).
First cost of water-works: $63,620 85.
Average annual cost of maintenance and repairs: $1,500.
Number of fire-plugs: 67.
Design and dimensions of pump and water-plunger: Made by R. D. Wood & Co., Philadelphia, Pennsylvania; plain double-plunger, 10 by 40 inches, 16 strokes per minute; pump-barrel 10 by 40 inches.
Time pump is run: 6 hours per day.
Description of force-main: 12 inches diameter; 40 pounds pressure on pump.
Description of water-valves: Rubber, 5¾ inches diameter, 1¼ inch lift.
Kind of power used: Water.
Description of water-wheel: Turbine, 36 inches diameter, made by R. D. Wood & Co.; 21 feet head, 115 revolutions per minute.
Cost of engine and pump: $6,000.
Remarks: Water slightly colored by vegetable matter in cedar-swamps.

OHIO.

LANCASTER:

Population: 6,803 inhabitants.
Name of corporation: Lancaster Water-Works (municipal)
Water obtained from: Hocking canal.
Water first introduced: In 1877.
Description of stand-pipe: 70 feet high.
Size of distributing mains: 6 inches.
Available head: 55 pounds (average).
Number of water-takers: 30.
First cost of water-works: $15,000.
Number of fire-plugs: 26.
Design of pump and water-plunger: Made by Smith, Vail, & Co., Dayton, Ohio.
Time pump is run: 1 hour per day.
Description of force-main: Head, 130 feet; 55 pounds pressure on pumps.
Kind of power used: Steam.
Description of boiler: Upright, 20 horse-power, 70 pounds pressure; fuel, soft coal.
Cost of engine and pump: $1,000.
Remarks: Canal water is unfit for use, but new works are in preparation and will be built in 1881.

PENNSYLVANIA.

BRISTOL:

Population: 5,273 inhabitants.
Name of corporation: The Bristol Water Company (private).
Water obtained from: Delaware river.
Water first introduced: February, 1875.
Description of stand-pipe: 140 feet high above stone foundation, 6 feet diameter.
Sizes of distributing mains: 12, 10, 8, and 4 inches.
Available head: 45 pounds (average).
Total length of distributing mains: 3½ miles.
Number of water-takers: 256.
Consumption of water: Average pumping, 140,000 gallons; 110,000 gallons are estimated to go to railroad company.
First cost of water-works: $39,450.
Average annual cost of maintenance and repairs: About $40.
Design and dimensions of pumps and water-plungers: Two direct-acting duplex, made by Worthington, New York, in 1875; 4 plain plungers, 10¼ inches diameter, 10 inches stroke, 23 strokes per minute (average).
Time pumps are run: About 10 hours per day.
Description of force-main: 20 feet long, 8 inches diameter, 45 pounds pressure on pumps.
Description of water-valves: Rubber, 3 inches diameter, ½ inch lift.
Kind of power used: Steam.
Description of boilers; Return tubular, 9 feet long, 44 inches diameter, 40 pounds pressure; fuel, pea coal.
Description of engine: Non-condensing, 16 by 10 inches, 132 strokes per minute; slide-valve operated by opposite piston.
Cost of engine and pumps: $5,500.
Duty of engine: 1,500,000 foot-pounds daily.

SOUTH CAROLINA.

CHARLESTON:

Population: 49,984 inhabitants.
Name of corporation: City Water-Works (private).
Water obtained from: Artesian well, 1,964 feet deep.
Area and capacity of reservoir: 3,300,000 gallons.
Water first introduced: In 1880.
Description of main conduit: ¼ mile long, 4 feet diameter; cast iron.
Description of stand-pipe: 76 feet high, 18 feet diameter, 90 feet above pump.
Sizes of distributing mains: 16, 12, 10, 8, and 6 inches.
Available head: 60 to 90 feet; water-supply deficient during very dry weather for a few hours daily.
Total length of distributing mains: 16 miles.
Number of water-takers: 500.

CHARLESTON—Continued.

Consumption of water: 210,000 gallons per day.
First cost of water-works: $400,000.
Average annual cost of maintenance and repairs: $7,000.
Number of fire-plugs: 208.
Design and dimensions of pump and water-plungers: Made by Knowles Manufacturing Company, New York, in 1880; plain plungers, 20 strokes per minute; pump-barrel, 20 by 36 inches.
Time pump is run: 3 to 4 hours per day.
Description of force-main: 80 feet long, 20 inches diameter; head, 90 feet; 38.98 pounds pressure on pump.
Description of water-valves: India-rubber, ¾ to 1 inch.
Kind of power used: Steam.
Description of boilers: 60 pounds pressure; fuel, anthracite coal.
Description of engine: Compound; high-pressure cylinder 20 inches diameter, 36 inch stroke; low-pressure cylinder, 38 inches diameter, 36 inches stroke; 32 to 44 strokes per minute; Knowles' valves and condenser.
Cost of engine and pump: $32,000.

TEXAS.

DALLAS:

Population: 10,358 inhabitants.
Name of corporation: Dallas Water-Supply Company (private).
Water obtained from: Wells, springs, and Trinity river.
Available head: 40 to 80 feet.
Consumption of water: 114,000 gallons daily.
Filtering apparatus: Gallery; gravel, not yet tested.
Design and dimensions of pump and water-plungers: Made by G. F. Blake Manufacturing Company, Chicago and Boston; one Blake plunger 24 inches; 103 steam-cylinder, 140 water-cylinder; one Knowles plunger, 10 inches, horizontal, 24-inch valve; 21-inch steam-cylinder; pump-barrels, 6 and 10 inches diameter.
Time pump is run: 16 hours per day.
Description of water-valves: Rubber, 50 inches diameter, 3 inches lift.
Kind of power used: Steam.
Description of engine: Simple, non-condensing.

WATER-WORKS EMPLOYING SYSTEM OF PUMPING DIRECT INTO DISTRIBUTING MAINS.

CALIFORNIA.

CHICO:

Population: 3,300 inhabitants.
Name of corporation: Chico Water Company (private).
Water obtained from: Well.
Water first introduced: In 1875.
Sizes of distributing mains: 8, 6, 4, and 3 inches.
Available head: 50 feet (average).
Total length of distributing mains: 5 miles.
Number of water-takers: 210.
Consumption of water: 300,000 gallons per day (estimated).
First cost of water-works: $50,000.
Average annual cost of maintenance and repairs: $4,200.
Number of fire-plugs: 30.
Design and dimensions of pump: Hooker pump, made by Garrett & Co., San Francisco, in 1875–'78; plain plunger, with metallic packing, 150 strokes per minute; pump-barrels, 2 and 8 inches diameter.
Time pump is run: 10 hours per day.
Time spent in repairs: 150 hours per year.
Description of force-main: 3,000 feet long, 8 inches diameter; 22½ to 26 pounds pressure on pump.
Description of water-valves: Rubber, 6 inches diameter, 1¼ inch lift.
Kind of power used: Steam.
Description of boilers: Two, 16 feet long, 42 inches diameter, 40 to 60 pounds pressure; fuel, wood.
Description of engines: 10 inches diameter, 16 inches stroke; 20 inches diameter, 24 inches stroke.
Cost of engines and pumps: $4,500.

SACRAMENTO:

Population: 21,420 inhabitants.
Name of corporation: Sacramento City Water-Works (municipal).
Water obtained from: Sacramento river.
Total area of water-shed available: 18,000 square miles.
Water first introduced: April, 1854.
Sizes of distributing mains: 20 to 3 inches.
Available head: 40 pounds (average).
Total length of distributing mains: About 25 miles.
Number of water-takers: 3,900.
First cost of water-works: $300,000.
Average annual cost of maintenance and repairs: $25,000.
Number of fire-plugs: 277.
Design and dimensions of pumps: One set, made by Holly Manufacturing Company, Lockport, New York; piston type water-plunger, double-acting, 10 inches diameter, 27¼ inches stroke, 75 to 80 strokes per minute; one Stevens, built by Central Pacific Railroad Company, Sacramento, California; plunger, 80 inches stroke, 24 inches diameter, 28 to 30 strokes per minute; pump-barrels: Holly, 10 by 35 inches; Stevens, 24 by 96 inches; head on pumps, 92.16 feet.
Time pumps are run: Constantly.
Description of water-valves: Stevens, rubber, ⅞ inch thick, 7 by 14 inches; Holly, iron plates, shod with rubber, 5 by 11 inches, 1 inch lift.
Kind of power used: Steam.

SACRAMENTO—Continued.

Description of boilers: Three tubular, 16 feet long, 60 inches diameter; 58 tubes, 4 inches diameter; 75 pounds pressure; fuel, gas-coke.
Description of engines: Holly, non-condensing, condensing, and compound; 16 inches diameter, 27¼ inches stroke, 75 to 80 strokes per minute; plain valves, with puppet cut-off; Stevens, condensing, 36 inches diameter, 80 inches stroke, 28 to 30 strokes per minute; balanced slide-valves; 2 air-pumps, 16 by 20 inches and 20 by 24 inches; condensers for both.
Cost of pumps and engines: Holly, $58,000; Stevens, $30,000.
Duty of engines: 1,000,000 foot-pounds per bushel of coke daily.
Remarks: The advantages of direct pumping are that pressure can be controlled, but when pumps stop working, the supply is also stopped.

COLORADO.

DENVER:

Population: 35,629 inhabitants.
Name of corporation; City Water Company (private).
Water obtained from: South Platte river.
Character and dimensions of dam: Dam across river, 3 miles south of Denver.
Cost of dam: $100,000.
Water first introduced: In 1870.
Description of main conduit: Canal, 2¼ miles long, 28 feet fall.
Sizes of distributing mains: 20 to 3 inches.
Total length of distributing mains: 35 miles.
Number of water-takers: 2,500.
Consumption of water: 75 gallons per head per day (exact).
First cost of water-works: $600,000.
Average annual cost of maintenance and repairs: $25,000.
Filtering apparatus: Gallery, 30 by 10 feet; sides and ends, 8 feet through; filled with sand and gravel; cleaned once a year.
Number of fire-plugs: 360.
Design and dimensions of pumps and water-plungers: Made by Holly Manufacturing Company, Lockport, New York, 1874; six bucket-plungers, 16 inches diameter, 16 inches stroke, 30 strokes per minute.
Time pumps are run: Constantly.
Description of force-main: 50 pounds pressure on pumps; domestic, 135 pounds pressure on pumps.
Description of water-valves: Old works, clack; new works, rubber disks.
Kind of power used: Steam and water.
Description of water-wheels: Two American turbines, made by Stout, Mills, & Temple, Dayton, Ohio; 54 inches diameter, 30 feet head, 115 revolutions per minute.
Description of boilers: Tubular, 54 inches diameter, 18 feet long; 16 flues, 6 inches diameter each; 7 pounds of water to 1 pound of coal; fuel, slack coal.
Description of engines: Compound; two 16 inches diameter, 27 inches stroke; one, 18 inches diameter, 27 inches stroke; one 25 inches diameter, 30 inches stroke; 15 to 115 strokes per minute (double); old works, slide- and puppet-valves; new works, puppet, operated by French cams; jet-condenser.
Cost of engines and pumps: $100,000.

PUEBLO:

Population: 3,217 inhabitants.
Name of corporation: Pueblo City Water-Works (municipal).
Water obtained from: Arkansas river.
Water first introduced: November, 1874.
Sizes of distributing mains: 12, 8, 6, and 4 inches.
Total length of distributing mains: 6½ miles.
Number of water-takers: 350.
Consumption of water: 375,000 gallons per day (estimated).
First cost of water-works: $120,000.
Average annual cost of maintenance and repairs: $6,500.
Filtering apparatus: Well, 50 feet diameter; gravel; cleaned once a year; settling reservoir being constructed, 100 by 500 feet.
Number of fire-plugs: 66.
Design and dimensions of pump and water-plungers: Made by Holly Manufacturing Company, Lockport, New York, 1874; four double-acting piston-plungers, 6½ inches diameter, 21 inches stroke, 10 strokes per minute; pump-barrel, 6½ by 21 inches.
Time pump is run: Constantly.
Description of force-main: 6½ miles long; head, 100 feet on pump.
Description of water-valves: Rubber, 8 inches long, 2 inches diameter, ¾ inch lift.
Kind of power used: Steam.
Description of boilers: Two return-flue, 12 feet long, 56 inches diameter; 41 tubes, 4 inches diameter each, 7 pounds pressure; fuel, screenings from lignite coal.
Description of engine: Usually compound, four cylinders, 10 inches diameter, 21 inches stroke, 20 strokes per minute; slide, also a variable cut-off valve; two air-pumps, 10 inches diameter, 12 inches stroke; jet-condenser.
Cost of engine and pump: $28,000.
Duty of engine: 3,000,000 foot-pounds to 100 pounds coal daily.
Remarks: The advantage of direct pumping into main is the control of pressure.

GEORGIA.

ATLANTA:

Population: 37,409 inhabitants.
Name of corporation: Atlanta Water-Works (municipal).
Water obtained from: Two small streams.
Capacity of reservoir: 258,000,000 gallons.
Character and dimensions of dam: 46 feet high, 300 feet wide at base, 12 feet wide at top; earth, with puddle wall in center.
Cost of dam: $46,997 46.
Water first introduced: In 1875.
Sizes of distributing mains: 12 to 4 inches.
Available head: 90 to 100 feet; water-supply deficient.
Total length of distributing mains: 14 miles.
Number of water-takers: 1,270.
Consumption of water: 2,250,000 gallons per day (average exact).
First cost of water-works: $350,000.
Average annual cost of maintenance and repairs: About $3,500.
Number of fire-plugs: 221.
Design and dimensions of pump and water-plunger: Made by Holly Manufacturing Company, Lockport, New York; plain plunger, 7¼ inches diameter, 27 inches stroke; strokes per minute vary; pump-barrel, 7¼ to 27 inches.
Time pump is run: Constantly.
Description of force-main: 3½ miles long, 16 inches diameter; 110 pounds pressure on pump.
Description of water-valves: Clack; 2 by 6 inches, ½ inch lift.
Kind of power used: Steam.
Description of boilers: Three tubular, 8 pounds pressure; fuel, bituminous coal.
Description of engine: Compound; 20 to 60 strokes per minute; slide-valves, with balance cut-off; jet-condenser.

ATLANTA—Continued.

Cost of engines and pumps: $50,000.
Duty of engine: About 55,000,000 foot-pounds daily.
Remarks: The advantage of pumping direct into distributing mains is (1) less first cost; (2) no greater cost to operate.

ILLINOIS.

DECATUR:

Population: 9,547 inhabitants.
Style of corporation: Municipal.
Water obtained from: Sangamon river.
Water first introduced: In 1871.
Description of main conduit: 300 feet long, 24 inches diameter; cast iron.
Discharging capacity: 17,000,000 gallons per 24 hours; 6 feet head (average).
Sizes of distributing mains: 12, 8, 6, 4, 2, and 1½ inches.
Available head: 150 feet (average).
Total length of distributing mains: 50,554 feet.
Number of water-takers: 275.
First cost of water-works: $75,000.
Average annual cost of maintenance and repairs: About $5,000.
Filtering apparatus: Gallery, 500 feet long, 4 feet below bed of river; 10 feet wide; 6-foot wall, with brick arch; filled with gravel.
Number of fire-plugs: 90.
Design and dimensions of pumps and water-plungers: Made by Cameron, New York; plain plunger, 12 inches diameter, 3 feet stroke, 15 to 30 strokes per minute; pump-barrel, 12 inches diameter.
Time pumps are run: Constantly.
Description of force-main: 5,280 feet long, 12 inches diameter; 70 pounds pressure on pumps.
Description of water-valves: Plain; 12, 6, and 4 inches.
Kind of power used: Steam.
Description of boilers: One tubular, 14 feet long; one flue, 20 feet long; 5 flues; 70 pounds pressure.
Description of engine: Non-condensing, simple; 18 inches diameter, 3 feet stroke, 15 to 20 strokes per minute; globe-valves; common air-chamber.
Cost of engines and pumps: Two Cameron, $3,000.
Duty of engines: 432,000 gallons in 24 hours, each pump, daily; 864,000 gallons in 24 hours, each pump, guaranteed.
Remarks: The advantage of pumping direct to mains consists in great pressure in case of fire.

GENESEO:

Population: 3,518 inhabitants.
Style of corporation: Municipal.
Water obtained from: Well.
Area and capacity of reservoir: 25 by 65 feet, 13 feet deep; 120,000 gallons.
Cost of dam: $1,000.
Water first introduced: October, 1879.
Description of distributing chamber: 5 feet diameter, 12 feet high; air-tight; made of boiler-iron; pump discharges into this chamber, and mains are connected with it.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 30 pounds (average).
Total length of distributing mains: About 1½ mile.
Number of water-takers: 60.
First cost of water-works: $14,500.
Average annual cost of maintenance and repairs: $1,025.
Number of fire-plugs: 14.
Design and dimensions of pump and water-plungers: Perkins, made by William Orten Manufacturing Company, Sterling, Illinois; 2 plain plungers, 12 by 8 inches diameter, 150 strokes per minute.
Time pump is run: Constantly.
Description of force-main: 30 pounds pressure on pump.
Description of water-valves: Area exceeds water-plungers; made of rubber, $\frac{3}{16}$ inch lift.
Kind of power used: Steam.

GENESEO—Continued.

Description of boilers: Two horizontal tubular, 12 feet long, 42 inches diameter; fuel, soft coal.

Description of engine: Non-condensing, single or duplex; 14 by 12 inches, 8 to 150 or 200 strokes per minute; common slide-valves.

Cost of engine and pump: $1,700.

Duty of engine: 1,000,000 gallons in 24 hours (daily).

Remarks: The advantage of pumping direct to distributing mains is control of pressure.

HYDE PARK:

Population: 15,716 inhabitants.

Name of corporation: Hyde Park Water-Works (municipal).

Water obtained from: Lake Michigan.

Water first introduced: In September, 1874.

Description of main conduit: 1,700 feet long, 16 inches diameter.

Sizes of distributing mains: 16 to 4 inches.

Available head: 110 feet (average).

Total length of distributing mains: About 29 miles.

Number of water-takers: 1,350.

Consumption of water: 1,229,134,425 gallons per year (exact).

First cost of water-works: $400,000.

Annual cost of maintenance and repairs: $6,924 13 in 1880.

Number of fire-plugs: 147.

Design and dimensions of pumps and water-plungers: Made by Holly Manufacturing Company, Lockport, New York; 4 piston-pumps, 9¼ inches diameter, 24 inches stroke, 10 to 40 strokes per minute; pump-barrel, 9¼ by 32 inches; one, made by Knowles, New York, plain plunger, 20 inches diameter, 36 inches stroke, 15 to 25 strokes per minute; pump-barrel, 12 inches long.

Time pumps are run: Constantly.

Time spent in repairs: 250 hours per year.

Description of force-main: 1¼ mile long, 16 inches diameter.

Description of water-valves: Holly, leather-faced hinge, 9 by 4 inches, 1¼ inch lift; Knowles, rubber disks, 3¼ inches diameter, ⅞ inch lift.

Kind of power used: Steam.

Description of boilers: Tubular, 16 feet long, 5 feet diameter, 75 pounds pressure; 7 2/10 pounds water to 1 pound coal; fuel, Indiana block bituminous coal.

Description of engines: Holly, non-condensing, condensing, or compound, at will; four cylinders, 14 by 24 inches, 10 to 40 strokes per minute; D-valve, puppet cut-off; two air-pumps, 14 inches diameter, 18 inches stroke; jet-condenser. Knowles, compound; high-pressure cylinder 20 inches diameter, low-pressure cylinder 38 inches diameter, 36 inches stroke, 15 to 25 strokes per minute; two air-pumps, 8 inches diameter, 18 inches stroke; D-valves worked by piston; jet-condenser.

Cost of engines and pumps: $40,000.

Duty of engines: 30,210,000 foot-pounds daily; Knowles, 60,000,000 foot-pounds guaranteed.

Remarks: The advantages of pumping direct into mains are cheapness of construction, and no fire-engines.—Water-works to point of distribution built and maintained in common with the town of Lake, Illinois.

LAKE:

Population: 18,380 inhabitants.

Style of corporation: Municipal.

Water obtained from: Lake Michigan.

Water first introduced: In 1874.

Description of main conduit: 16 inches in diameter.

Discharging capacity: 5,000,000 gallons.

Sizes of distributing mains: 12, 10, 8, 6, 4, and 3 inches.

Available head: 20 pounds (average); water-supply deficient.

Total length of distributing mains: 70 miles.

Number of water-takers: 2,400.

Consumption of water: About 150 gallons per head per day (estimated).

First cost of water-works: $700,000.

LAKE—Continued.

Average annual cost of maintenance and repairs: $18,000.

Number of fire-plugs: 300.

Design and dimensions of pumps and water-plungers: Made by Holly Manufacturing Company, piston-plunger, and, made by Knowles, plain plunger; 22 strokes per minute; pump-barrel, 9 by 20 inches.

Time pumps are run: Constantly.

Description of force-main: 8 miles long, 16 inches diameter, 60 pounds pressure on pumps.

Description of water-valves: Holly, foot-valves, 4 feet by 7 inches; Knowles, rubber, 4 inches.

Kind of power used: Steam.

Description of boilers: Tubular, 60 pounds pressure; fuel, Indiana block bituminous coal.

Description of engine: Compound, 52 strokes per minute; slide-valves: ordinary air-pump; jet-condenser.

Cost of engine and pumps: $50,000.

Duty of engine: 28,000,000 foot-pounds daily; 60,000,000 foot-pounds guaranteed.

Remarks: Water-works to point of distribution built and maintained in common with the town of Hyde Park, Illinois.

MOLINE:

Population: 7,800 inhabitants.

Style of corporation: Municipal.

Water obtained from: Mississippi river, above government dam.

Water first introduced: In 1877.

Description of main conduit: 500 feet long, 12 inches diameter; cast iron.

Discharging capacity: 100 pounds steam will discharge 1,000 gallons per minute.

Sizes of distributing mains: 8 and 4 inches.

Available head: 100 pounds (average).

Total length of distributing mains: 3,727 feet and 6,378 feet.

Number of water-takers: 52.

Consumption of water: 720,000 gallons in 24 hours (estimated).

First cost of water-works: $12,000.

Average annual cost of maintenance and repairs: $300.

Number of fire-plugs: 47.

Design and dimensions of pumps and water-plungers: One Knowles and two Worthington duplex; two plain plungers, 10 inches diameter, 24 inches stroke, 150 strokes per minute; pump-barrels, 10 inches each.

Time pumps are run: 24 hours per day.

Description of force-main: 50 pounds pressure on pumps.

Description of water-valves: Vulcanized rubber, 3 inches diameter, ⅝ inch lift.

Kind of power used: Steam.

Location of boilers: Located at saw-mill of Dunnock, Gould, & Co.

Description of engine: Simple, non-condensing; 18 inches diameter, 24 inches stroke, 150 strokes per minute; Knowles patent valves.

Cost of engine and pumps: $2,300.

Remarks: The advantage of pumping direct into distributing mains is perfect control of pressure; the disadvantage is that water is less pure.

RAVENSWOOD:

Population: 485 inhabitants.

Style of corporation: Municipal.

Water obtained from: Lake Michigan.

Water first introduced: In May, 1876.

Sizes of distributing mains: 14 to 4 inches.

Available head: 40 pounds (average).

Total length of distributing mains: 21 miles.

Consumption of water: 500,000 gallons per day (estimated).

First cost of water-works: $200,000.

Average annual cost of maintenance and repairs: $5,000.

Number of fire-plugs: 78.

RAVENSWOOD—Continued.

Design and dimensions of pump and water-plungers: Made by Flanders, Vergennes, Vermont; plain plungers, 5 to 35 strokes per minute; pump-barrels: No. 1, 20 by 14 inches; No. 2, 30 by 12 inches.

Time pump is run: Constantly.

Description of force-main: 25 miles long, 14 to 4 inches diameter.

Description of water-valves: Hard rubber.

Kind of power used: Steam.

Description of boilers: Two tubular, 16 feet long; 50 flues; 80 pounds pressure.

Description of engines: Condensing; one set 20 by 14 inches; one set Harris-Corliss, 20 by 14 inches; 20 strokes per minute; No. 1, slide-valves; two single-acting air-pumps; No. 2, Corliss valve, drop cut-off; one double-acting air-pump; jet-condenser.

Cost of engines and pump: $25,000.

ROCHELLE:

Population: 1,893 inhabitants.

Style of corporation: Municipal.

Water obtained from: Water-shed, fed by springs.

Capacity of reservoir: 7,000,000 gallons.

Water first introduced: In 1877.

Sizes of distributing mains: 8 and 6 inches.

Available head: 40 pounds (average).

Total length of distributing mains: 8,500 feet.

Number of water-takers: 70.

First cost of water-works: $16,000.

Average annual cost of maintenance and repairs: $2,000.

Number of fire-plugs: 24.

Design and dimensions of pumps and water-plungers: Two; made by Worthington; duplex, 16 by 10 by 10¼ inches; bucket-plunger, 4 inches; 10¼ inches; 300 strokes per minute.

Time pumps are run: 16 hours per day.

Description of force-main: 4,335 feet long.

Description of water-valves: Rubber and spiral springs, 2¼ inches diameter; lift, small.

Kind of power used: Steam.

Description of boilers: One horizontal; 39 4-inch flues; 14 feet long, 50 inches diameter; one 50 horse-power Firmenick.

Description of engine: Non-condensing; 16 inches diameter, 10 inches stroke.

Cost of engine and pumps: $3,000.

Duty of engine: 800 gallons per minute each, daily; 1,000 gallons per minute guaranteed.

STOCKYARD STATION:

Population: 4,400 inhabitants.

Name of corporation: Town Lake (municipal).

Water obtained from: Lake Michigan.

Water first introduced: In 1874.

Description of main conduit: 16 inches diameter.

Discharging capacity: 5,000,000 gallons; 110 pounds pressure (average).

Sizes of distributing mains: 12, 10, 8, 6, 4, and 3 inches.

Available head: 20 pounds (average); water-supply deficient.

Total length of distributing mains: 70 miles.

Number of water-takers: 2,400.

Consumption of water: 150 gallons per head per day (estimated).

First cost of water-works: $750,000.

Average annual cost of maintenance and repairs: $18,000.

Number of fire-plugs: 300.

Design and dimensions of pumps and water-plungers: Made by Holly Manufacturing Company, piston-plunger; made by Knowles, plain plunger; 22 strokes per minute; pump-barrels, 9 by 20 inches.

Time pumps are run: Constantly.

Time spent in repairs: None.

Description of force-main: 8 miles long, 6 inches diameter; head, 60 pounds (average) on pumps.

Description of water-valves: Foot-valves—Holly, 4 by 7 inches; Knowles, rubber, 4 inches.

STOCKYARD STATION—Continued.

Kind of power used: Steam.

Description of boiler: Tubular, 60 pounds pressure; 7½ pounds water to 1 pound coal; fuel, Indiana block bituminous coal.

Description of engine: Compound; 52 strokes per minute; slide-valves; common air-pump; jet-condenser.

Cost of engine and pumps: $50,000.

Duty of engine: 28,000,000 gallons daily.

Remarks: The advantage of pumping direct to mains is the saving of stand-pipe.

SYCAMORE:

Population: 3,028 inhabitants.

Name of corporation: Sycamore Water-Works (municipal).

Water obtained from: Well.

Water first introduced: In 1876.

Size of distributing mains: 10 inches.

First cost of water-works: About $25,000.

Number of fire-plugs: 15.

Design of pump and water-plunger: Blake pump, Boston, Massachusetts, 1875.

Kind of power used: Steam.

Cost of engine and pump: $2,000.

INDIANA.

BRAZIL:

Population: 3,441 inhabitants.

Style of corporation: Municipal.

Water obtained from: Well.

Total area of water-shed available: 13 acres

Water first introduced: In 1875.

Description of reservoir: A well, 25 feet in diameter.

Size of distributing mains: 8 inches.

Total length of distributing mains: About 2½ miles.

Number of water-takers: About 50.

Consumption of water: 22 gallons per head per day (estimated).

First cost of water-works: $28,500.

Average annual cost of maintenance and repairs: About $1,400.

Number of fire-plugs: 22.

Design and dimensions of pump and water-plunger: Made by Deane Brothers, Indianapolis, Indiana; plain plunger, 10 inches diameter; 15 strokes per minute; pump-barrel, 10 inches diameter.

Time pump is run: 18 hours per day.

Time spent in repairs: 28 hours per year.

Description of water-valves: Gum; 6 inches diameter, 1¼ inch lift.

Kind of power used: Steam.

Description of boilers: Tubular, 14 feet long; 40 pounds pressure; fuel, the slack of block coal.

Description of engine: Non-condensing; 16 inches diameter, 18 inches stroke, 15 strokes per minute; throttle-valves.

Cost of engine and pump: About $12,000.

COLUMBUS:

Population: 4,813 inhabitants.

Name of corporation: Columbus Water-Works (municipal).

Water obtained from: White river.

Water first introduced: In 1871.

Sizes of distributing mains: 10, 8, and 6 inches.

Total length of distributing mains: 8 miles.

Number of water-takers: 200.

First cost of water-works: $80,000.

Average annual cost of maintenance and repairs: $5,000.

Filtering apparatus: Gallery, 500 feet long, 16 feet wide, 16 feet deep, filled with gravel, imbedded 4 feet below bottom of river; sides and top closed; no cleaning.

Number of fire-plugs: 80.

Design and dimensions of pump and water-plunger: Made by Holly Manufacturing Company, Lockport, New York; plain plunger, 12 inches diameter, 24 inches stroke, 19 to 20 strokes per minute.

Time pump is used: Constantly.

Time spent in repairs: 150 hours per year.

COLUMBUS—Continued.

Kind of power used: Steam.

Description of boilers: Two; 14 feet long, 48 inches diameter; 48 flues.

Description of engine: Condensing, simple; 14 inches diameter, 2 feet stroke, 40 strokes per minute; direct-acting slide-valves.

Cost of engine and pump: $45,000.

CONNERSVILLE:

Population: 3,228 inhabitants

Name of corporation: Connersville Hydraulic Company.

Water obtained from: White Water river.

Character and dimensions of dam: 600 feet long, 6 feet high; frame.

Water first introduced: In 1869.

Sizes of distributing mains: 8, 6, and 4 inches.

Available head: 18 feet (average).

Total length of distributing mains: About 4 miles.

Number of water-takers: 325.

Consumption of water: 1,000,000 gallons per day (estimated).

First cost of water-works: $42,000.

Average annual cost of maintenance and repairs: About $5,000.

Number of fire-plugs: 50.

Design and dimensions of pump and water-plunger: Double 8-inch rotary pump.

Time pump is run: Constantly.

Time spent in repairs: One month per year.

Description of force-main: 3 miles long, 8, 6, and 4 inches diameter; 20 pounds pressure on pump.

Kind of power used: Water.

Description of water-wheels: Two turbines, one Holly, and one Eclipse, 30 and 36 inches diameter, made by Pierce Manufacturing Company; 14 feet head, 150 revolutions per minute.

Remarks: Water is from canal, and, of course, not good for drinking, but answers the purpose it is generally put to.

EVANSVILLE:

Population: 29,280 inhabitants.

Name of corporation: Evansville Water-Works (municipal).

Water obtained from: Ohio river.

Water first introduced: June, 1872.

Description of main conduit: 2,300 feet long, 24 inches diameter; cast iron.

Sizes of distributing mains: 20 and 12 inches.

Total length of distributing mains: 25 miles.

Number of water-takers: 1,306.

First cost of water-works: $328,319 06.

Filtering system: Sand and gravel.

Number of fire-plugs: 228.

Design and dimensions of pump and water-plungers: Made by Holly Manufacturing Company, Lockport, New York; four bucket-plungers, 36 inches diameter, 18 inches stroke, double-acting, 16 strokes per minute; pump-barrel, 18 by 36 inches.

Time pump is run: Constantly.

Description of force-main: Head, 154 feet on pump.

Description of water-valves: Four; rubber; 8 inches diameter, 1½ inch lift.

Kind of power used: Steam.

Description of boilers: Four; 16 feet long, 4 feet diameter; 12 flues, 6 inches each; 90 pounds pressure; 8.85 pounds of water to 1 pound coal; fuel, anthracite coal.

Description of engine: Compound condensing; high-pressure cylinder 24 inches diameter, low-pressure cylinder 41 inches diameter, 36 inches stroke; balanced puppet operated by cams; Buckley injector condenser.

Cost of engine and pump: $26,000.

Duty of engine: 88,000,000 foot-pounds daily; 80,000,000 foot-pounds guaranteed.

LOGANSPORT:

Population: 11,198 inhabitants.

Style of corporation: Municipal.

Water obtained from: Eel river.

Total area of water-shed available: 3,600 square miles.

LOGANSPORT—Continued.

Character and dimension of dam: 500 feet long, 6 feet deep (average); wooden.

Cost of dam: $7,000.

Water first introduced: In 1876.

Description of main conduit: 2,000 feet long, 20 inches diameter; cast iron.

Discharging capacity: 3,000,000 gallons per 24 hours.

Sizes of distributing mains: 20, 16, 12, 10, 8, 6, 4, and 2 inches.

Available head: 40 pounds (average).

Total length of distributing mains: 10½ miles.

Number of water-takers: 400.

Consumption of water: 500,000 gallons per day (estimated).

First cost of water-works: $185,000.

Average annual cost of maintenance and repairs: $25,000.

Number of fire-plugs: 84.

Design and dimensions of pumps and water-plungers: Made by Cope & Maxwell, Hamilton, Ohio; 4 piston-pumps, 11 inches diameter, 24 inches stroke; pump-barrel, 11 by 24 inches.

Time pumps are run: Constantly.

Description of water-valves: Rubber, 6½ by 1 inch thick.

Kind of power used: Steam and water.

Description of water-wheels: 3 Little Giant turbines; two 54 inches, one 42 inches; 11 feet head.

Description of boilers: Two; 12 feet long, 62 inches diameter; 100 tubes, 2½ inches diameter.

Description of engines: Compound; two 10 inches and two 20 inches, 8-inch crank, 14 strokes per minute; slide eccentric valves.

Cost of engines and pumps: $21,000.

Duty of engines: 8,370,535 foot-pounds daily; 4 tons coal per day.

MARION:

Population: 3,182 inhabitants.

Name of corporation: Marion Water-Works (municipal).

Water obtained from: Flowing river.

Water first introduced: In 1877.

Sizes of distributing mains: 12, 8, 6, and 4 inches.

Available head: 40 pounds (average).

Total length of distributing mains: 7 miles.

Number of water-takers: 300.

Consumption of water: 336,000 gallons per day (estimated).

First cost of water-works: $34,000.

Number of fire-plugs: 44.

Design and dimensions of pump and water-plungers: Made by Deane Brothers, Indianapolis, Indiana; two plain plungers, 10 inches diameter, 14½ inches stroke, 8 strokes per minute; pump-barrel, 14½ by 10 inches.

Time pump is run: Constantly.

Description of force-main: ½ mile long, 12 inches diameter, 40 pounds pressure on pumps.

Description of water-valves: Rubber, 6 inches.

Kind of power used: Steam.

Description of boilers: 13 feet long, 48 inches diameter, 35 pounds pressure; fuel, Pittsburgh coal.

Description of engine: Duplex, 18 inches diameter, 14 inches stroke; 8 strokes per minute; independent cut-off, double valve.

Cost of engine and pump: $4,000.

Duty of engine: 465,000 gallons per day.

UNION CITY:

Population: 2,478 inhabitants.

Style of corporation: Municipal.

Water obtained from: Well.

Water first introduced: January, 1874.

Description of main conduit: 10 inches diameter; wood, coated with coal-tar or asphaltum and bound with strap-iron.

Sizes of distributing mains: 10, 8, 6, and 4 inches.

Available head: 60 to 70 pounds.

Number of water-takers: 167.

Consumption of water: 150,000 gallons per day (estimated).

First cost of water-works: $50,000.

UNION CITY—Continued.

Average annual cost of maintenance and repairs: $2,700 to $3,500.

Number of fire-plugs: 20.

Design and dimensions of pump and water-plungers: Deane Brothers, makers, Indianapolis, 1873; plain plungers.

Time pump is run: Constantly.

Kind of power used: Steam.

Description of boilers: Tubular, 60 to 70 pounds pressure; fuel, Hocking Valley and Pittsburgh coal.

IOWA.

CEDAR RAPIDS:

Population: 10,104 inhabitants.

Name of corporation: Cedar Rapids Water Company (private).

Water obtained from: Cedar river.

Water first introduced: In 1875.

Sizes of distributing mains: 16 to 4 inches.

Total length of distributing mains: 7¾ miles.

Number of water-takers: 330.

Consumption of water: 600,000 gallons per day (estimated).

First cost of water-works: $119,245.

Average annual cost of maintenance and repairs: $13,000.

Number of fire-plugs: 76.

Design and dimensions of pumps and water-plungers: Made by McGowan Pump Company, Cincinnati, Ohio, 1875; 4 duplex double-acting plungers; 2 cylinders, 30 inches diameter, 30 inches stroke; 2 cylinders, 10 inches diameter, 24 inches stroke; two 20 and two 40 strokes per minute; pump-barrels, 10 by 24 inches and 14 by 30 inches.

Time pumps are run: Constantly.

Time spent in repairs: 250 hours per year.

Description of force-main: 1,600 feet long, 16 inches diameter, 60 pounds pressure on pumps.

Description of water-valves: Disk, in 2 cylinders, 8 inches diameter, 1 inch lift; clapped in 2 cylinders, 6 feet by 9 inches, 3 inches lift.

Kind of power used: Steam.

Description of boilers: Two, tubular, 14 feet long, 60 inches diameter, 70 pounds pressure; fuel, bituminous coal.

Description of engines: One compound condensing, 26½ by 30 inches, and 28 by 30 inches; 20 strokes per minute; 1 piston-valve; 1 condensing or non-condensing, 16 inches diameter, 24 inches stroke, 40 strokes per minute; 1 slide-valve; piston air-pump, and jet-condenser, 100 gallons per minute.

Cost of engines and pumps: $21,760.

Duty of engines: 600,000 gallons with 60 pounds pressure daily; 4,000,000 gallons per 24 hours guaranteed.

Remarks: The advantage and disadvantage of pumping direct to mains are best system for fire purposes, but more expensive for general use.

DAVENPORT:

Population: 21,831 inhabitants:

Name of corporation: Davenport Water Company (private).

Water obtained from: Mississippi river.

Water first introduced: In 1874.

Description of main conduit: 150 feet long, square, and arched on top; brick; extends into river.

Sizes of distributing mains: 14, 12, 10, 8, 6, and 4 inches.

Available head: 80 to 90 pounds.

Total length of distributing mains: 22 miles.

Number of water-takers: 650.

Consumption of water: 3,000,000 gallons per day (estimated).

First cost of water-works: About $500,000.

Average annual cost of maintenance and repairs: About $26,000.

Number of fire-plugs: 242.

Design and dimensions of pump and water-plungers: Made by Todd & Rafferty, Paterson, New Jersey, 1874; two plain plungers, 17 inches diameter, 6 feet stroke, double-acting, 6 to 12 strokes per minute; pump-barrel, 17 inches diameter.

DAVENPORT—Continued.

Time pumps are run: Constantly.

Description of force-main: 14 inches diameter, 80 to 90 pounds pressure on pump.

Description of water-valves: Rubber disks, 14 inches diameter, ½ to 1 inch lift.

Kind of power used: Steam.

Description of boilers: Two-flue, 24 feet long, 52 inches diameter, 75 pounds pressure; 5 pounds water to 1 pound coal; fuel, bituminous coal.

Description of engine: Non-condensing, 24 inches diameter, 36 inches stroke, 60 strokes per minute; slide-valves.

DES MOINES:

Population: 22,408 inhabitants.

Name of corporation: Des Moines Water-Works Company (private).

Water obtained from: Raccoon river.

Water first introduced: In 1872.

Description of main conduit: 1,000 feet long, 16 inches diameter; iron.

Sizes of distributing mains: 16, 12, 10, 8, 6, and 4 inches.

Total length of distributing mains: 20 miles.

Number of water-takers: 1,200.

Consumption of water: 2,000,000 gallons per day (estimated).

First cost of water-works: $350,000.

Filtering apparatus: One 14 inches diameter and one 8 inches diameter, made of boiler-iron.

Number of fire-plugs: 187.

Design and dimensions of pumps and water-plungers: Made by Holly Manufacturing Company, Lockport, New York, in 1871; 8 bucket-plungers, 14 inches diameter, 12 inches stroke; pump-barrels, 14 inches diameter; 4 rotary pumps, 12 by 19 inches; 80 to 150 pounds pressure on pumps.

Time pumps are run: Constantly.

Description of water-valves: Rubber, 13 inches diameter, 2 inches lift.

Kind of power used: Steam.

Description of boilers: 2 vertical and 2 horizontal; 70 pounds pressure; fuel, bituminous coal.

Description of engine: Interchangeable, 14 inches diameter, 24 inches stroke, Holly valve; air-pump, 14 by 14 inches; surface-condenser, 12 feet high, 30 inches diameter.

Cost of engine and pumps: $50,000.

KEOKUK:

Population: 12,117 inhabitants.

Name of corporation: Keokuk Water-Works (private).

Water obtained from: Mississippi river.

Water first introduced: July, 1878.

Description of main conduit: Length 250 feet, diameter 20 inches; cast iron,

Discharging capacity: 2,220,000 gallons per 24 hours.

Sizes of distributing mains: 14 to 6 inches.

Available head: 35 to 75 pounds.

Total length of distributing mains. 11 miles.

Number of water-takers: 396.

Consumption of water: 70 gallons per head per day (estimated).

First cost of water-works: $100,000.

Average annual cost of maintenance and repairs: $5,000.

Filtering apparatus: Size, 60 feet long, 15 feet deep; filled with fine and coarse sand, gravel, charcoal, and broken rock, in layers; cleaned once in two years.

Number of fire-plugs: 76.

Design and dimensions of pump and water-plungers: Made by Holly Manufacturing Company, Lockport, New York, in in 1878; four plain plungers, 8 inches diameter, 22 inches stroke; pump-barrel, 8 inches diameter.

Time pump is run: Constantly.

Description of force-main: 14 inches diameter, 60 to 120 pounds pressure on pump.

Kind of power used: Steam.

KEOKUK—Continued.

Description of boilers: Two; 16 feet long, 5 feet diameter; 34 flues, 3½ inches diameter, 60 to 80 pounds pressure; 7 to 8 pounds water to 1 pound coal; fuel, Iowa bituminous coal.

Description of engines: Interchangeable, 4 cylinders, 14½ inches diameter, 22 inches stroke; slide-valves operated by eccentric; air-pump, 14 by 12 inches; condenser, 12,200 cubic inches.

Cost of engine and pump: $20,000.

Duty of engine: 400,000 gallons daily.

Remarks: The advantage and disadvantage of pumping direct to mains are control of pressure, but it is wearing on machinery.

MARENGO:

Population: 1,738 inhabitants.

Style of corporation: Municipal.

Water obtained from: Mill-dam.

Water first introduced: In 1875.

Sizes of distributing mains: 6 and 4 inches.

Total length of distributing mains: 1½ mile.

First cost of water-works: $8,000.

Average annual cost of maintenance and repairs: $100.

Number of fire-plugs: 10.

Design of pump and water-plunger: Made by Worthington, New York.

Kind of power used: Water.

Description of water-wheels: Two turbines.

MARSHALLTOWN:

Population: 6,240 inhabitants.

Name of corporation: Marshalltown Water-Works (municipal).

Water obtained from: Iowa river.

Water first introduced: October, 1876.

Sizes of distributing mains: 12 to 4 inches.

Available head: 35 pounds (average).

Total length of distributing mains: 7.9 miles.

Number of water-takers: 425.

Consumption of water: 250,000 gallons per day (estimated).

First cost of water-works: $46,500.

Average annual cost of maintenance and repairs: $3,380.

Filtering apparatus: A large well, 17 by 34 feet; charcoal and gravel, 2 feet thick.

Number of fire-plugs: 69.

Design and dimensions of pump and water-plunger: Made by Knowles, Warren, Massachusetts; plain plunger, 12 inches diameter, 24 inches stroke.

Time pump is used: Constantly.

Description of water-valves: Rubber, 3½ inches diameter, ½ inch lift.

Kind of power used: Steam.

Description of boilers: Two, tubular, 14 feet long, 48 inches diameter; 52 tubes, 3 inches diameter, 75 pounds pressure; fuel, soft coal.

Description of engine: Simple, 22 by 24 inches, 1 to 80 strokes per minute; puppet- and slide-valves.

Cost of engine and pump: $5,000.

MONTICELLO:

Population: 1,877 inhabitants.

Style of corporation: Municipal.

Water obtained from: Artesian well.

Capacity of reservoir: 250,000 gallons.

Cost of dam: $1,000.

Water first introduced: October, 1879.

Description of main conduit: ½ mile long, 8 inches diameter; cast iron.

Sizes of distributing mains: 8, 6, and 4 inches.

Available head: 120 feet (average).

Total length of distributing mains: 2 miles.

Number of water-takers: 65.

Consumption of water: 12,000 gallons per day (estimated).

First cost of water-works: $15,000.

Average annual cost of maintenance and repairs: $900.

Number of fire-plugs: 20.

MONTICELLO—Continued.

Design and dimensions of pump and water-plunger: Made by Blake & Co., Boston, Massachusetts; plain plunger, 8 inches diameter, 12 inches stroke, 80 to 120 strokes per minute; pump-barrel, 8 by 12 inches.

Time pump is run: 20 to 25 hours per week.

Time spent in repairs: 250 hours per year.

Description of force-main: Head, 125 feet on pump.

Description of water-valves: Rubber, 3 inches diameter.

Kind of power used: Steam.

Description of boilers: Upright, 10 feet high, 4 feet diameter; fuel, wood.

Description of engine: Non-condensing, simple, 14 inches diameter, 12 inches stroke, 90 strokes per minute.

Cost of engine and pump: $1,000.

OSKALOOSA:

Population: 4,598 inhabitants.

Name of corporation: Oskaloosa Water Company (private).

Water obtained from: Skunk river.

Water first introduced: August, 1880.

Description of main conduit: 10 miles long, 10 inches diameter; cast iron.

Discharging capacity: 2,000,000 gallons per day, 60 to 80 pounds pressure.

Sizes of distributing mains: 8, 6, and 4 inches.

Available head: 35 pounds (average).

Total length of distributing mains: 4½ miles.

Number of water-takers: 60.

First cost of water-works: $102,000.

Filtering apparatus: Pit in solid rock, 40 by 15 feet, 3 feet below bed of stream; charcoal, sand, and gravel in alternate layers; cleaned once a year.

Number of fire-plugs: 49.

Design and dimensions of pump and water-plunger: Made by Holly Manufacturing Company, Lockport, New York; plain plunger; pump-barrel, 10 inches diameter.

Time pump is run: Constantly.

Description of force-main: 4 miles long, 10 inches diameter; head, 114 feet on pump.

Description of water-valves: Iron and rubber.

Kind of power used: Steam.

Description of boilers: 18 feet long, 52 inches diameter; 40 tubes.

Description of engine: One quadruplex compound condensing; 4 pumps; 1 duplex high-pressure pump.

KANSAS.

EMPORIA:

Population: 4,631 inhabitants.

Name of corporation: Emporia Water-Works (municipal).

Water obtained from: Cottonwood river.

Total area of water-shed available: 1 mile.

Water first introduced: June, 1880.

Description of main conduit: 8 inches diameter.

Discharging capacity: 2,000,000 gallons per day; 100 pounds pressure (average).

Sizes of distributing mains: 12 to 8 inches.

Available head: Variable.

Total length of distributing mains: 11½ miles.

Number of water-takers: 104.

Consumption of water: 10,000 gallons per day (estimated).

First cost of water-works: $62,500.

Average annual cost of maintenance and repairs: $4,500.

Number of fire-plugs: 47.

Design and dimensions of pump and water-plunger: Made by Holly Manufacturing Company, Lockport, New York; plain plunger, 6 inches diameter, 21 inches stroke, 12 strokes per minute; pump-barrel, 6 by 21 inches.

Time pump is run: Constantly.

Description of force-main: 5,000 feet long, 8 inches diameter, 45 pounds pressure on pump.

Description of water-valves: Hinge, 4 by 6 inches, ⅝ inch lift.

EMPORIA—Continued.

Kind of power used: Steam.

Description of boilers: Tubular, 54 inches diameter, 50 pounds pressure; fuel, Little Pittsburgh coal.

Description of engine: Condensing compound, 16 by 21 inches, 6 strokes per minute; slide-valves by eccentric; surface condenser.

Cost of engine and pump: $15,000.

Advantage of pumping direct into main: Economy in fuel, and control of pressure.

KENTUCKY.

OWENSBOROUGH:

Population: 6,231 inhabitants.

Name of corporation: Owensborough Water Company (private).

Water obtained from: Ohio river.

Water first introduced: July, 1879.

Sizes of distributing mains: 10, 8, 6, 4, and 3 inches.

Available head: 80 feet (average).

Total length of distributing mains: 9 miles and 570 feet.

Number of water-takers: 254.

Consumption of water: 10 gallons per day per head (estimated).

First cost of water-works: $80,000.

Average annual cost of maintenance and repairs: $6,000.

Number of fire-plugs: 74.

Design and dimensions of pump and water-plungers: Made by Holly Manufacturing Company, Lockport, New York, in 1879; two plain and solid plungers, 14 inches diameter, 30 inches stroke, 10 strokes per minute; pump-barrel, 14 by 36 inches.

Time pump is run: Constantly.

Time spent in repairs: 7 days per year.

Description of force-main: 300 feet long, 10 inches diameter, 40 to 45 pounds pressure on pump.

Description of water-valves: Hinge or gate, 10 degrees from horizontal; size, 12 by 5 inches; 1¼ inch lift.

Kind of power used: Steam.

Description of boilers: Tubular, 18 feet long, 5 feet diameter; evaporation, 2,100 pounds water per hour with 220 pounds coal.

Description of engine: Non-condensing or condensing; 25 inches diameter, 30 inches stroke, 20 strokes per minute; throttle-valve; horizontal air-pump, 9 by 12; Holly condenser.

Cost of engine and pump: $15,000.

Duty of engine: 75,000 gallons of water, daily; 2,000,000 gallons guaranteed.

Disadvantage of pumping direct to main: Not economical, either in labor or fuel.

MASSACHUSETTS.

TAUNTON:

Population: 21,213 inhabitants.

Name of corporation: Taunton Water-Works (municipal).

Water obtained from: Taunton river.

Water first introduced: December, 1876.

Sizes of distributing mains: 20, 16, 12, 10, 8, 6, and 4 inches.

Available head: 80 feet.

Total length of distributing mains: 35 miles.

Number of water-takers: 1,800.

Consumption of water: 510,261 gallons per day (exact).

First cost of water-works: $250,000.

Average annual cost of maintenance and repairs: About $9,000.

Filtering system: Old basin is a canal 400 feet long, 100 feet wide on top; inner slope, 2 to 1; bottom 8 feet below mean water-mark. New basin is an egg-shaped conduit, laid along river, distant 30 feet; supplied by driven wells; bricks laid in hydraulic cement, with end-joints left open and uncemented material, gravel.

TAUNTON—Continued.

Number of fire-plugs: 320.

Design and dimensions of pumps and water-plungers: Made by Holly Manufacturing Company, Lockport, New York; 4 plain plungers, 9⅝ inches diameter, 24 inches stroke; strokes per minute according to demand; pump-barrel, 9⅝ inches diameter.

Time pumps are run: Constantly.

Description of water-valves: Cylindrical; plugs, iron stems, covered with leather, 1½ inch diameter, ½ inch lift.

Kind of power used: Steam.

Description of boilers: Three tubular, 16 feet long, 60 inches diameter; 54 tubes, 3¾ inches diameter; 80 pounds pressure; fuel, Hazleton Lehigh egg coal.

Description of engine: Compound, 14 inches diameter, 24 inches stroke. Two rotary pumps, 20½ inches diameter, 30 inches stroke; strokes per minute variable.

Cost of engine and pumps: $62,000.

Duty of engine: 37,311,024 foot-pounds daily; 40,000,000 foot-pounds guaranteed.

Advantage of pumping direct into mains: Very best protection against fire. Extraordinary power can be had almost instantly.

MICHIGAN.

ALLEGAN:

Population: 2,305 inhabitants.

Style of corporation: Municipal.

Water obtained from: Wells.

Water first introduced: In 1871.

Description of main conduit: 12 and 4 inches diameter.

Sizes of distributing mains: 12 to 4 inches.

Available head: 60 feet (average).

Total length of distributing mains: 3 miles.

Number of water-takers: 150.

Consumption of water: 43,200 gallons per day (exact).

First cost of water-works: $50,000.

Average annual cost of maintenance and repairs: $1,500.

Number of fire-plugs; 30.

Design of pump and water-plungers: Made by Holly Manufacturing Company, Lockport, New York; rotary pump, 60 strokes per minute.

Time pump is run: Constantly.

Kind of power used: Water.

Description of water-wheels: Two Holly turbines, 8 feet head, 60 revolutions per minute.

Cost of engine and pump: $12,000.

Advantage of pumping direct into mains: Keeps pressure on.

ALPENA:

Population: 6,153 inhabitants.

Name of corporation: Alpena City Water-Works (private).

Water obtained from: Lake Huron.

Water first introduced: October, 1879.

Description of main conduit: Wood.

Sizes of distributing mains: 16, 12, 10, 8, 6, and 4 inches

Total length of distributing mains: 50,419 feet.

Number of water-takers: 250.

First cost of water-works: $56,000.

Average annual cost of maintenance and repairs: $2,000.

Number of fire-plugs: 80.

Design of pump and water-plungers: Made by Holly Manufacturing Company, Lockport, New York.

Time pump is run: Constantly.

Time spent in repairs: None.

Kind of power used: Water.

Description of water-wheels: One 50-inch and one 84-inch Leffel; one duplex pump, 2 by 9 by 18 inches; two Holly rotary No. 10.

BAY CITY:

Population: 20,693 inhabitants.

Style of corporation: Municipal.

Water obtained from: Saginaw bay.

Water first introduced: December, 1872.

BAY CITY—Continued.

Description of main conduit: $4\frac{386}{5280}$ miles long, 30 and 18 inches diameter; wooden staves, 3 inches thick, banded together every 2 feet with elm bands, laid in lengths of 8 feet.

Discharging capacity: 5,000,000 gallons in 24 hours; head, 10 feet (average).

Sizes of distributing mains: 16, 12, 10, 8, 6, and 4 inches.

Available head: About 60 feet (average).

Total length of distributing mains: 19½ miles.

Number of water-takers: 800.

Consumption of water: 2,266,000 gallons per day (exact).

First cost of water-works: $365,000.

Average annual cost of maintenance and repairs: $10,000.

Number of fire-plugs: 138.

Design and dimensions of pumps and water-plungers: Made by Holly Manufacturing Company, Lockport, New York, in 1872; 4 double-acting pistons, 9 inches diameter, 24 inches stroke, 30 strokes per minute; pump-barrel, 9 by 24 inches, two rotary; 40 pounds pressure on pumps.

Time pumps are run: Constantly.

Description of water-valves: Hinged, packed with leather, 6 by 10 inches.

Kind of power used: Steam.

Description of boilers: Horizontal tubular, 16 feet long, 5½ feet diameter, 70 pounds pressure; fuel, pine slabs.

Description of engines: Simple, compound condensing or non-condensing at will—14 by 24 inches, 140 strokes per minute; one high-pressure non-condensing, 18 and 22 inches, 320 strokes per minute; plain slide-valves, automatic cut-off, worked by cams; single-acting air-pump, 14 inches diameter, 24 inches stroke; jet-condenser.

Cost of engines and pumps: $39,000.

Duty of engines: 40,000,000 foot-pounds daily.

Advantage of pumping direct into mains: Control of pressure.

BIG RAPIDS:

Population: 3,552 inhabitants.

Name of corporation: Big Rapids Water-Works (municipal).

Water obtained from: Muskegon river.

Water first introduced: In 1871.

Sizes of distributing mains: 8, 6, and 4 inches.

Available head: Domestic purposes, 65 pounds pressure (average); fire purposes, 100 pounds pressure (average).

Total length of distributing mains: 3½ miles.

Number of water-takers: 200.

Consumption of water: 22,000,000 gallons per month (estimated).

First cost of water-works: $65,000.

Average annual cost of maintenance and repairs: $3,500.

Number of fire-plugs: 24.

Design and dimensions of pump and water-plungers: Made by Holly Manufacturing Company, Lockport, New York, and two Blake (New York) plain plungers; 5 to 25 strokes per minute; pump-barrels, Blake, 14 by 12 inches and 19 by 12 inches.

Time pump is run: Constantly.

Description of water-valves: Rubber, 3 inches size, ½ inch lift.

Kind of power used: Steam.

Description of boilers: 10 feet long, 5 feet diameter; fuel, pine wood.

Description of engines: Holly compound, 10 inches diameter, 21 inches stroke; large Blake, 20 inches diameter, 24 inches stroke; small Blake, 12 inches diameter, 14 inches stroke; 5 to 150 strokes per minute; D-valves; Holly air-pump.

Cost of engines and pump: $12,000.

Duty of engines: 2,000,000 gallons in 24 hours guaranteed.

CADILLAC:

Population: 2,213 inhabitants.

Name of corporation: Cadillac City Water-Works (private).

Water obtained from: Clam lake.

CADILLAC—Continued.

Total area of water-shed available: 200 square miles.

Water first introduced: In 1879.

Sizes of distributing mains: 6 and 4 inches.

Available head: 60 pounds (average).

Total length of distributing mains: 3 miles.

Number of water-takers: 400.

First cost of water-works: $15,000.

Average cost of maintenance and repairs: $1,010.

Number of fire-plugs: 14.

Design and dimensions of pump and water-plungers: Made by Dixon, Ferrisburg, Michigan, 1879; plain plungers, one 10 by 24 inches and one 6½ by 12 inches; small, 200 strokes per minute; large, 140 strokes per minute; pump-barrels, 6½ by 12 inches and 9 by 24 inches.

Time pump is run: Constantly.

Description of water-valves: Rubber.

Kind of power used: Steam.

Description of boilers: Two tubular, 10 feet long, 44 inches diameter; 12 feet long, 60 inches diameter; fuel, wood.

Description of engines: Simple, non-condensing; one 18 by 24 inches and one 12 by 12 inches; 140 and 200 strokes per minute; one exhaust- and one slide-valve, operated by puppet-arm.

Cost of engines and pump: $2,000.

CONSTANTINE:

Population: 1,405 inhabitants.

Style of corporation: Municipal.

Water obtained from: Fawn river.

Water first introduced: In 1878.

Size of distributing mains: 10 inches.

Total length of distributing mains: 1 mile.

First cost of water-works: $5,000.

Average annual cost of maintenance and repairs: About $100.

Number of fire-plugs: 7.

Design and dimensions of pump and water-plunger: Ferry pump, built at Ottier Iron Works, Ferrisburg, Michigan, in 1878; plunger, 9 inches diameter, 18 inches stroke, 80 strokes per minute; pump-barrel, 9 inches diameter.

Time pump is run: Constantly.

Description of force-main: 1 mile long, 10 inches diameter; head 60 feet on pump.

Description of water-valves: Common lap, 6 by 3 inches.

Kind of power used: Water.

Description of water-wheels: Two Leffel turbines, 36 and 42 inches diameter, 15 feet head, 120 revolutions per minute.

EAST SAGINAW:

Population: 19,016 inhabitants.

Name of corporation: East Saginaw Water-Works (municipal).

Water obtained from: Saginaw river.

Water first introduced: January, 1874.

Description of main conduit: 585 feet long, 30 inches diameter; wood.

Sizes of distributing mains: 16 to 2 inches.

Available head: 40 pounds (average).

Total length of distributing mains: $21\frac{4518}{5280}$ miles.

Number of water-takers: 800.

Consumption of water: 72 gallons per head per day (estimated).

First cost of water-works: $300,000.

Average annual cost of maintenance and repairs: $8,571.

Number of fire-plugs: 149.

Design and dimensions of pump and water-plungers: Made by Holly Manufacturing Company, Lockport, New York; 4 plain plungers, 9 inches diameter, 24 inches stroke, 20 strokes per minute; pump-barrel, 24 by 9 inches.

Time pump is run: Constantly.

Description of force-main: 40 pounds pressure on pump.

Description of water-valves: Leather, 5 by 9 inches, 2 inches lift.

Kind of power used: Steam.

Description of boilers: Three horizontal, 16 feet long, 5 feet diameter; 58 flues, 3½ inches diameter.

EAST SAGINAW—Continued.

Description of engines: Two pair, double-cylinder, condensing, 21 strokes per minute; slide-valves operated by eccentric; one Holly rotary, 150 horse-power.

Cost of pump and engines: $32,000.

HOLLY:

Population: 1,443 inhabitants.

Style of corporation: Municipal.

Water obtained from: Mill-pond and Shiawassee river.

Water first introduced: In 1880.

Sizes of distributing mains: 8 and 6 inches.

Total length of distributing mains: About 2 miles.

First cost of water-works: $9,000.

Average annual cost of maintenance and repairs: $1,300.

Number of fire-plugs: 16.

Design and dimensions of pump and water-plungers: Pattee & Perkins patent, Sterling, Illinois; two plain plungers, 7 inches diameter, 12 inches stroke, 100 strokes per minute; pump-barrel, 12 inches diameter.

Time pump is run: Constantly.

Description of water-valves: Rubber.

Kind of power used: Steam.

Description of boilers: 14 feet long, 3 feet diameter, 30 pounds pressure; fuel, bituminous coal.

Description of engine: Simple, non-condensing, 12 by 14 inches; slide-valves worked by eccentric.

Cost of engine and pump: $1,000.

Remarks: The only impurities are from vegetable matter.

JACKSON:

Population: 16,105 inhabitants.

Name of corporation: Jackson City Water-Works (municipal).

Water obtained from: Artesian wells.

Water first introduced: In 1870.

Sizes of distributing mains: 15, 12, 6, and 4 inches.

Available head: 40 pounds (average).

Total length of distributing mains: 12 miles.

Number of water-takers: About 600.

Consumption of water: 782,203 gallons per day (estimated).

First cost of water-works: $140,000.

Average annual cost of maintenance and repairs: $6,800.

Number of fire-plugs: 85.

Design and dimensions of pumps and water-plungers: Two rotary and piston, made by Holly Manufacturing Company, Lockport, New York, in 1870–'72; two piston plungers, 27 by 10 inches, 30 strokes per minute; pump-barrel, 10 inches diameter.

Time pumps are run: Constantly.

Description of force-main: 12 miles long, 15 to 4 inches diameter; head, 115 feet on pumps.

Description of water-valves: Flap, 4½ by 10 inches, ½ inch lift.

Kind of power used: Steam.

Description of boilers: Tubular, 14 feet long, 5 feet diameter; fuel, bituminous coal.

Description of engines: Two condensing, 16 inches diameter, 27 inches stroke, 100 strokes per minute; common slide-valves, with puppet cut-off; simple acting air-pump, 14 inches stroke, half of area of cylinder; one rotary 150 horse-power.

Cost of engines and pumps: $40,000.

Duty of engines: 15,021,400 foot-pounds daily.

MARQUETTE:

Population: 4,690 inhabitants.

Style of corporation: Municipal.

Water obtained from: Lake Superior.

Water first introduced: In 1870.

Description of main conduit: 200 feet long, 24 inches diameter; iron.

Sizes of distributing mains: 8, 6, 4, 3, 2, and 1½ inches.

Available head: 20 to 50 pounds; water-supply deficient.

Total length of distributing mains: 34,500 feet.

Number of water-takers: 550.

MARQUETTE—Continued.

Consumption of water: 100 gallons per head per day (estimated).

First cost of water-works: $100,000.

Average annual cost of maintenance and repairs: $6,500.

Number of fire-plugs: 53.

Design and dimensions of pumps and water-plungers: One set Holly in 1869; one set Murrett in 1873; plungers double and single bucket, 6–8 inches Holly, 8–12 inches Murrett; 10 to 15 strokes per minute; pump-barrel, 12 by 12 inches.

Time pumps are run: Constantly.

Time spent in repairs: 7 days per year.

Description of force-main: 5,000 feet long, 8 inches diameter, 80 pounds pressure on pumps.

Description of water-valves: Leather foot; rubber bucket, 12 inches, 4 feet lift.

Kind of power used: Steam.

Description of boilers: One upright flue, 10 feet long, 7 feet diameter; one horizontal flue, 14 feet long, 5 feet diameter.

Description of engines: Simple; one 14 by 24 inches, 50 to 100 strokes per minute; one 18 by 24 inches, 30 to 50 strokes per minute.

Cost of engines and pumps: $43,000.

MUSKEGON:

Population: 11,262 inhabitants.

Name of corporation: Muskegon City Water-Works (municipal).

Water obtained from: Springs.

Total area of water-shed available: 30 acres.

Capacity of reservoir: 5,500,000 gallons.

Water first introduced: In 1875.

Sizes of distributing mains: 16, 12, 8, 6, and 4 inches.

Available head: 40 pounds (average).

Total length of distributing mains: 15 miles.

Number of water-takers: 482.

Consumption of water: 70 gallons per head per day (estimated).

First cost of water-works: $160,000.

Average annual cost of maintenance and repairs: $4,900.

Number of fire-plugs: 184.

Design and dimensions of pump and water-plungers: Flanders, made at Vergennes, Vermont; two sets plain duplex plungers, 14 by 20 inches, 3 to 24 strokes per minute.

Time pump is run: Constantly.

Time spent in repairs: 80 hours per year.

Description of force-main: 2,115 feet long, 16 inches diameter, 40 to 70 pounds pressure on pump.

Description of water-valves: Hard rubber, 6 inches.

Kind of power used: Steam.

Description of boilers: Two tubular, 16 feet long, 68 inches diameter, 70 pounds pressure; fuel, pine slabs.

Description of engine: Simple; 16 by 32 inches, 24 to 192 strokes per minute; globe-valves.

Cost of pump and engine: $27,000.

Remark: Only trouble is from vegetable matter in reservoir.

PORT HURON:

Population: 8,883 inhabitants.

Style of corporation: Municipal.

Water obtained from: Saint Clair river.

Water first introduced: In 1872.

Sizes of distributing mains: 16 to 2 inches.

Available head: 70 feet (average).

Total length of distributing mains: 18 miles.

Number of water-takers: About 1,200.

Consumption of water: 500,000 gallons per day (estimated).

First cost of water-works: $170,000.

Average annual cost of maintenance and repairs: About $6,500.

Number of fire-plugs: 108.

Design and dimensions of pump and water-plungers: Made by Holly Manufacturing Company, Lockport, New York; 4 plain plungers, 9 inches diameter, 24 inches stroke, 18 strokes per minute; pump-barrel, 9 by 24 inches.

PORT HURON—Continued.

Time pump is run: Constantly.
Description of force-main: 30 pounds pressure on pumps.
Description of water-valves: Leather hinge, 3½ by 7 inches.
Kind of power used: Steam.
Description of boilers: Two tubular, 16 feet long, 5 feet diameter; 72 tubes, 4 inches each; 25 pounds pressure; fuel, bituminous coal.
Description of engine: Condensing or compound, at will; 4 cylinders, 14 by 24 inches, each, 80 strokes per minute; slide-valves with variable cut-off; common bucket air-pump, 14 by 16 inches; jet-condenser.
Cost of engine and pump: $25,000.

SAGINAW:

Population: 10,525 inhabitants.
Name of corporation: Saginaw Water-Works (municipal).
Water first introduced: In 1872.
Sizes of distributing mains: 16, 10, 8, 6, and 4 inches.
Available head: 45 pounds (average).
Total length of distributing mains: 8½ miles.
Number of water-takers: 250.
Consumption of water: 1,000,000 gallons per day (estimated).
First cost of water-works: $150,000.
Average annual cost of maintenance and repairs: $8,500.
Number of fire-plugs: 124.
Design and dimensions of pumps and water-plungers: Made by Holly Manufacturing Company, Lockport, New York; 4 plain piston-plungers, 9 inches diameter, 24 inches stroke, 18 to 60 strokes per minute; pump-barrel, 9 by 24 inches, double-acting; two rotary pumps No. 10.
Time pumps are run: Constantly.
Description of water-valves: Hinge, with leather, 10 to 8½ inches long, 4 inches wide, 1 inch lift.
Kind of power used: Steam.
Description of boilers: Two tubular, 16 feet long, 5 feet diameter, 70 pounds pressure; fuel, wood.
Description of engines: Compound condensing, 14 by 24 inches 4 cylinder, slide-valves, rock-shaft; single air-pump; jet condenser; one rotary engine.
Cost of engines and pumps: $33,000.

SAINT LOUIS:

Population: 1,975 inhabitants.
Style of corporation: Municipal.
Water obtained from: Pine river.
Character and dimensions of dam: 600 feet long, running obliquely across Pine river.
Water first introduced: In 1880.
Sizes of distributing mains: 8, 6, and 4 inches.
Total length of distributing mains: 1¾ mile.
Number of water-takers: 69.
First cost of water-works: $7,500.
Average annual cost of maintenance and repairs: $50.
Number of fire-plugs: 23.
Time pumps are run: Steam 2 months, water 10 months per year.
Kind of power used: Steam and water.
Cost of engine and pumps: Steam $2,000, water $500.

MINNESOTA.

MANKATO:

Population: 5,550 inhabitants.
Name of corporation: Mankato Water-Works (municipal).
Water obtained from: Minnesota river.
Total area of water-shed available: About 5,000 square miles.
Water first introduced: September, 1879.
Description of main conduit: 433 feet long, 12 inches diameter; iron.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 40 pounds, or 92 feet (average).
Total length of distributing mains: 13,573 feet.
Number of water-takers: 6.

MANKATO—Continued.

First cost of water-works: $16,047 67.
Average annual cost of maintenance and repairs: $2,500.
Number of fire-plugs: 30.
Design and dimensions of pump and water-plungers: One Knowles, made at Warren, Massachusetts; one plain plunger, 1 to 175 strokes per minute; pump-barrel, 12 by 40 inches.
Time pumps are run: Constantly.
Description of force-main: 92 feet long, 12 inches diameter, 40 pounds pressure on pump.
Kind of power used: Steam.
Description of boilers: Pump run by boilers at mill; fuel, wood.
Cost of pump: $1,500.
Remarks: Direct pumping into mains is the only plan available.—Water is drawn below the city and is impregnated with sewage.

MINNEAPOLIS:

Population: 46,887 inhabitants.
Style of corporation: Municipal.
Water obtained from: Mississippi river.
Capacity of reservoir: 19,585 gallons.
Cost of dams: $28,000.
Water first introduced: In 1867.
Sizes of distributing mains: 2 to 16 inches.
Available head: 40 pounds (average).
Total length of distributing mains: 22 miles.
Number of water-takers: 1,600.
Consumption of water: 3,500,000 gallons per day (exact).
First cost of water-works: $450,000.
Average annual cost of maintenance and repairs: $11,000.
Number of fire-plugs: 268.
Design and dimensions of pumps and water-plungers: No. 1, James Waters, built by Charles M. Hardenbury, Minneapolis, Minnesota; double-acting plunger with low piston, 9 inches diameter, 24 inches stroke, 60 strokes per minute; pump-barrel, 9 by 50 inches. Nos. 2 and 3, built by Holly Manufacturing Company, Lockport, New York; double-acting plunger, with low piston, 16 inches diameter, 24 inches stroke, 30 strokes per minute; pump-barrels, 16 by 60 inches.
Time pumps are run: 8,350 hours per year.
Time spent in repairs: 410 hours per year.
Description of force-main: 16 inches diameter.
Description of water-valves: Rubber, 5 by ¾ inches, ½ inch lift.
Kind of power used: Water.
Description of water-wheels: Two American turbines, 48 inches diameter, 31 feet head, 120 revolutions per minute; 10.75 gallons of water required to lift 1 gallon.

NEW JERSEY.

RAHWAY:

Population: 6,455 inhabitants.
Name of corporation: Rahway Water-Works (municipal).
Water obtained from: North branch of Rahway river.
Total area of water-shed available: About 30 square miles.
Water first introduced: In 1872.
Sizes of distributing mains: 14 to 6 inches.
Available head: 120 feet (average).
Total length of distributing mains: About 5 miles.
Number of water-takers: 700.
Consumption of water: 500,000 gallons per day (average).
First cost of water-works: $135,000.
Average annual cost of maintenance and repairs: $4,500.
Filtering apparatus: Clark filter, 16 feet square; sand, 6 inches deep, on fine wire-cloth; cleaned once in 24 hours.
Number of fire-plugs: 130.
Design and dimensions of pumps and water-plungers: Two duplex Worthington, New York, 1872; plain plungers, 10 and 14 inches diameter, 24 inches stroke, 28 strokes per minute (average), or 7 counter-strokes; pump-barrel, 5 feet by 18 inches.

RAHWAY—Continued.

Time pumps are run: One always in motion, 45 pounds pressure on pumps (average).
Time spent in repairs: 500 hours per year.
Kind of power used: Steam.
Description of boilers: Tubular, 16 feet long, 5 feet diameter, 50 pounds pressure; 10 pounds water to 1 pound coal; fuel, extra good pea coal.
Description of engine: Compound high-pressure cylinder 20 inches diameter, low-pressure cylinder 33 inches diameter, 24 inches stroke; average, 7 counter-strokes per minute; slide-valve worked by opposite piston; 2 air-pumps, single; capacity, $\frac{2}{10}$ of cylinder; jet-condenser, capacity, $\frac{3}{4}$ of cylinder.
Duty of engine: Average 30,000,000 foot-pounds daily.
Remarks: The advantage of pumping direct into mains is that it saves expense of reservoir and long conduits; also fire apparatus.—Water generally good; in spring polluted by refuse of felt factory above, also dead vegetable matter.

NEW YORK.

AUBURN:

Population: 21,924 inhabitants.
Name of corporation: The Auburn Water-Works Company (private).
Water obtained from: Owasco lake.
Total area of water-shed available: 100,000 acres.
Water first introduced: In 1866.
Size of distributing mains: 12 inches.
Available head: 40 pounds (average).
Total length of distributing mains: 23 miles.
Number of water-takers; 1,000.
Consumption of water: 87 gallons per head per day (estimated).
First cost of water-works: $175,000.
Number of fire-plugs: 250.
Design of pumps and water-plungers: Made by Holly Manufacturing Company, Lockport, New York.
Time pumps are run: Constantly.
Description of force-main: 3 miles long, 12 inches diameter.
Kind of power used: Steam and water.
Description of water-wheels: Two American turbines, 84 and 66 inches diameter; head, 16 feet (maximum). One Holly turbine, 66 inches diameter; head, 12 feet (average).
Description of boilers: One tubular upright, 7 feet diameter; one horizontal, 5 feet diameter; 80 pounds pressure.
Description of engines: Four Holly; cylinders, 14 by 24 inches; can be changed to high-pressure or compound at will; Buckley condenser.
Duty of engines: 60,000,000 foot-pounds daily.

BATAVIA:

Population: 4,845 inhabitants.
Style of corporation: Municipal.
Water obtained from: Tonawanda creek.
Total area of water-shed available: 20 square miles.
Character and dimensions of dam: Mill-dam, 99 feet wide, 14 feet high.
Cost of dam: It is owned by Batavia Mills; water supplied at $1,000 per year for ten years.
Water first introduced: In 1874.
Size of distributing mains: 8 inches.
Total length of distributing mains: About 2 miles.
Consumption of water: 4,000 gallons per day (estimated).
First cost of water-works: $30,000.
Average annual cost of maintenance and repairs: $1,300.
Number of fire-plugs: 41.
Time pumps are run: 3 hours per week.
Kind of power used: Steam and water.
Description of water-wheel; Ordinary mill-wheel.

COLLEGE POINT:

Population: 4,192 inhabitants.
Name of corporation: College Point Water-Works (municipal).
Water obtained from: Fresh Meadow springs.

COLLEGE POINT—Continued.

Total area of water-shed available: 9½ square miles.
Capacity of reservoir: 2,500,000 gallons, fed by springs.
Cost of dam: $12,000.
Water first introduced: January, 1875.
Description of main conduit: 40 feet long, 8 feet diameter; brick and planked bottom.
Sizes of distributing mains: 12, 10, 8, and 6 inches.
Available head: 50 pounds, or 133 feet (average).
Total length of distributing mains: 13.8 miles.
Number of water-takers: 410.
Consumption of water: 364,562 gallons per day, or 81 gallons per head (estimated).
First cost of water-works: $212,500.
Average annual cost of maintenance and repairs: $5,000.
Filtering apparatus: 3 graded galvanized-iron screens.
Number of fire-plugs: 56.
Design and dimensions of pump and water-plungers: Built by H. R. Worthington, New York, in 1874; plain plungers, 13 and 14 inches diameter, 24 inches stroke, 9 strokes per minute.
Time pump is run: Constantly.
Time spent in repairs: 2 hours per day per year.
Description of force-main: 24,747 feet long, 12 inches diameter, 50 pounds pressure on pump.
Description of water-valves: Rubber.
Kind of power used: Steam.
Description of boilers: Two tubular flue, 15 feet long, 50 inches diameter, 50 pounds pressure; fuel, Lehigh egg coal.
Description of engine: One compound high-pressure cylinder, 17¼ inches diameter; low-pressure cylinder, 34 inches diameter, 24 inches stroke; one high-pressure, 20 inches diameter, 15 inches stroke; 18 strokes per minute each; ordinary slide-valves, worked by piston-rod; 2 air-pumps, and tank for steam.
Cost of engine and pump: $17,500.
Duty of engine: 37,830,900 foot-pounds daily; 63,927,100 foot-pounds guaranteed.
Remark: A gradual accumulation of fungi matter in hot months.

COOPERSTOWN:

Population: 2,199 inhabitants.
Name of corporation: Cooperstown Aqueduct Association (private).
Water obtained from: Otsego lake.
Total area of water-shed available: About 50 square miles.
Area and capacity of reservoir: 15 square miles, 40 feet deep (average).
Water first introduced: In 1835.
Description of main conduit: 4,300 feet long, 10 inches diameter; cast iron.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 45 to 70 feet.
Consumption of water: 60 gallons per head per day (domestic); 100 gallons per minute for fire.
Average annual cost of maintenance and repairs: $400.
Number of fire-plugs: 25.
Design and dimensions of pumps and water-plungers: Two built by H. R. Worthington, New York, in 1880; direct double-acting, 4 cylinders, 8¼ inches diameter, 10½ inches stroke.
Time pumps are run: Constantly.
Description of force-main: 40 to 100 pounds pressure on pumps.
Description of water-valves: Rubber, ½ inch lift.
Kind of power used: Water.
Description of water-wheels: Two 50-inch Leffel turbines, double-acting, special, 7 feet head, 80 revolutions per minute.
Cost of engine and pumps: $4,000.

DUNKIRK:

Population: 7,248 inhabitants.
Name of corporation: Dunkirk Water-Works (municipal).

DUNKIRK—Continued.

Water obtained from: Lake Erie.
Water first introduced: July, 1872.
Description of main conduit: 900 feet long, 12 inches diameter; iron, extending into lake with 40 square feet crib at end, made of wood.
Discharging capacity: 2,500,000 gallons.
Sizes of distributing mains: 12 to 3 inches.
Available head: 100 feet (average).
Total length of distributing mains: About 14 miles.
Number of water-takers: 600.
Consumption of water: 1,000,000 gallons per day (estimated).
First cost of water-works: $107,000.
Average annual cost of maintenance and repairs: $6,000.
Number of fire-plugs: 80.
Design and dimensions of pumps and water-plungers: Built by Holly Manufacturing Company, Lockport, New York; 4 plain piston, 9½ inches diameter, 24 inches stroke, 24 strokes per minute; pump-barrel, 9½ by 24 inches; two rotary pumps.
Time pumps are run: Constantly.
Description of main conduit: 14 miles long, 47.64 pounds pressure on pumps.
Description of water-valves: Leather hinge, 10 by 5 inches, ⅝ inch lift.
Kind of power used: Steam.
Description of boilers: Return tubular, 16 feet long, 60 inches diameter; 7 pounds of water to 1 pound coal, 45 pounds pressure; fuel, slack coal.
Description of engine: Non-condensing, 14 by 24 inches, 48 strokes per minute; slide-valve operated by eccentric from shaft.
Cost of pumps and engine: $45,000.
Duty of engine: 55,000,000 foot-pounds daily.

GARDEN CITY:

Population: 574 inhabitants.
Name of corporation: Garden City Water-Works (private).
Water obtained from: Wells.
Total area of water-shed available: About 50 square miles.
Water first introduced: In 1876.
Sizes of distributing mains: 16, 10, 8, 6, and 4 inches.
Available head: About 35 pounds (average).
Total length of distributing mains: 8½ miles.
Number of water-takers: 125.
Consumption of water: 500,000 gallons per day (estimated).
First cost of water-works: $250,000.
Number of fire-plugs: 25.
Design and dimensions of pump and water-plungers: Built by Holly Manufacturing Company, Lockport, New York, in 1876; 4 plain plungers, 7¾ inches in diameter, 22 inches stroke, 20 strokes per minute; pump-barrel, 7¾ by 22 inches.
Time pump is run: Constantly.
Description of water-valves: Solid rubber, 1$\frac{15}{16}$ inches diameter, ½ inch lift.
Kind of power used: Steam.
Description of boiler: Plain cylinder, 35 pounds pressure; fuel, white-ash coal, grate size.
Description of engine: 20 strokes per minute; slide-valve operated by eccentric; Holly air-pump and condenser.
Cost of engine and pump: About $25,000.

GOUVERNEUR:

Population: 2,071 inhabitants.
Name of corporation: Gouverneur Water-Works (private).
Water obtained from: Oswegatchie river.
Water first introduced: In 1867.
Description of main conduit: Cast iron and cement.
Sizes of distributing mains: 6 and 4 inches.
Available head: 32 pounds (average); water-supply deficient.
Total length of distributing mains: 2 miles.
Number of water-takers: 70.
First cost of water-works: $29,000.

GOUVERNEUR—Continued.

Average annual cost of maintenance and repairs: $500.
Number of fire-plugs: 14.
Design and dimensions of pump and water-plungers: Green rotary, built by Bailey & Sewall, Watertown, New York; 100 to 175 strokes per minute; pump-barrels, 15 and 18 inches diameter.
Time pump is run: Constantly.
Time spent in repairs: 304 hours per year.
Description of force-main: 32 pounds pressure on pump.
Description of water-valves: Slide and tumblers.
Kind of power used: Water.
Description of water-wheels: One Holly and one Weaver turbine; 7 to 9 revolutions per minute.
Remarks: The disadvantage of pumping direct into mains is that when pressure is used for fire purposes it is felt by all dwellings.

JORDAN:

Population: 1,344 inhabitants.
Name of corporation: S. L. Rockwell & Co. (private).
Water obtained from: Skaneateles outlet.
Water first introduced: In 1880.
Description of main conduit: 2,300 feet long, 3½ inches diameter; wrought iron.
Size of distributing mains: 3½ inches.
Total length of distributing mains: 2,300 feet.
First cost of water-works: $2,000.
Number of fire-plugs: 4.
Design and dimensions of pump and water-plunger: Built by S. Button & Son, Waterford, New York, in 1880; one plain plunger, 6 inches diameter, 6 inches stroke, 200 strokes per minute; pump-barrel, 6 by 6 inches.
Description of water-valves: Plain brass.
Kind of power used: Water.
Description of water-wheels: One Bodine-Jonval turbine, 40 inches diameter, 10 feet head, 114 revolutions per inute.
Remark: Water used only for fire purposes.

LOCKPORT:

Population: 13,522 inhabitants.
Name of corporation: No specific name; the Holly Manufacturing Company owns the machinery and the city owns the pipes.
Water obtained from: Erie canal.
Water first introduced: In 1869.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 230 feet on pumps, 150 feet on distribution (average).
Total length of distributing mains: About 7 miles.
Number of water-takers: 430.
Consumption of water: 80 gallons per head (estimated).
Average annual cost of maintenance and repairs: About $2,000.
Number of fire-plugs: 110.
Design and dimensions of pump and water-plungers: Built by Holly Manufacturing Company, Lockport, New York, in 1871; 4 plain plungers, 9 inches diameter, 20 to 50 strokes per minute; pump-barrel, 9 by 24 inches.
Time pump is run: Constantly.
Description of force-main: 12 inches diameter, 100 to 140 pounds pressure on pump.
Description of water-valves: Plain hinge-valves, faced with leather.
Kind of power used: Water.
Description of water-wheels: American turbine, 42 inches diameter, made by Stout, Mills & Temple, Dayton, Ohio; 56 feet head; revolutions, according to consumption.
Cost of engine and pump: $10,000.
Remark: The advantage of pumping direct into mains consists in this, that the head can be varied to meet demand.—Water is unfit for domestic use, owing to impurities resulting from sewerage.

LONG ISLAND CITY:

Population: 17,129 inhabitants.
Name of corporation: Long Island City Water Company (municipal).
Water obtained from: Driven wells.
Water first introduced: In 1875.
Description of main conduit: 16 inches diameter; cast iron.
Sizes of distributing mains: 16, 12, 10, 8, and 6 inches.
Available head: 25 pounds (average); water-supply deficient.
Total length of distributing mains: 16 miles.
Number of water-takers: 861.
Consumption of water: About 1,200,000 gallons per day (estimated).
First cost of water-works: $350,000.
Average annual cost of maintenance and repairs: $19,000.
Design of pumps and water-plungers: Built by Holly Manufacturing Company, Lockport, New York, and by Guild & Garison, Brooklyn, New York.
Time pumps are run: Constantly.
Kind of power used: Steam.
Remarks: The advantage of pumping direct into mains is that the force can be increased to meet the wants of extinguishing fires without steam or hand fire-engines.

NIAGARA FALLS:

Population: 3,320 inhabitants.
Name of corporation: Niagara Falls Water-Works Company (private).
Water obtained from: Niagara river.
Cost of dam: Water-works to point of distribution owned by Suspension Bridge Water-Works Company.
Water first introduced: July, 1877.
Sizes of distributing mains: 10 to 4 inches.
Available head: 70 pounds (average).
Total length of distributing mains: 5 miles.
Consumption of water: 1,500,000 gallons per day (estimated).
First cost of water-works: $30,000.
Average annual cost of maintenance and repairs: $100.
Number of fire-plugs: 31.
Kind of power used: Water.
Remarks: The advantage of pumping direct into mains is economy; the disadvantage, that supply ceases when pumps stop for repairs.

OGDENSBURG:

Population: 10,341 inhabitants.
Name of corporation: Ogdensburg Water-Works (municipal).
Water obtained from: Oswegatchie river.
Water first introduced: November, 1868.
Sizes of distributing mains: 12, 10, 8, 6, 4, and 3 inches.
Available head: 40 pounds (average).
Total length of distributing mains: 14 miles.
Number of water-takers: 1,100.
Consumption of water: 1,000,000 gallons per day (exact).
First cost of water-works: $150,000.
Average annual cost of maintenance and repairs: Extension, $6,430; materials, $176 62.
Number of fire-plugs: 82.
Design and dimensions of pumps and water-plungers: One Lang, built at Burlington, Vermont; one Flanders, built at Vergennes, Vermont; two plain plungers to each pump; one 14 inches diameter, 30 inches stroke; one 14 inches diameter, 20 inches stroke; 28 strokes per minute; pump-barrel, 14 inches diameter; total capacity, 5,000,000 gallons.
Time pumps are run: Constantly.
Description of force-main: 40 pounds pressure on pumps.
Description of water-valves: Rubber disks; Lang, 14 inches diameter; Flanders, 9 inches diameter; 1 inch lift (average).
Kind of power used: Steam and water.
Description of water-wheels: Two Holly turbines, 72 inches diameter; one Gates-Curtis turbine, 56 inches diameter; 4 to 13 feet head (fluctuating); 40 to 75 revolutions per minute.
Description of boilers: Marine return-flue; fuel, bituminous coal.

OGDENSBURG—Continued.

Description of engine: Non-condensing, 16 inches diameter, 36 inches stroke, 45 strokes per minute; slide-valves operated by eccentric on crank-shaft, with graduating cut on main-valve driven by eccentric.
Cost of engine and pumps: $16,200.
Remarks: The advantage of pumping direct into mains is that but 40 pounds pressure are maintained under ordinary circumstances.

OLEAN:

Population: 3,036 inhabitants.
Name of corporation: Olean Water-Works (municipal).
Water obtained from: Olean creek.
Water first introduced: In 1877.
Sizes of distributing mains: 6 and 4 inches.
Total length of distributing mains: 3 miles.
Consumption of water: 100,000 gallons per day.
Average annual cost of maintenance and repairs: $1,500.
Design and dimensions of pump and water-plunger: Built by W. H. Kelly, New Brunswick, New Jersey; plain plunger, 6 inches diameter, 75 strokes per minute; pump-barrel, 6 inches diameter.
Time pump is run: Constantly.
Description of force-main: 50 pounds pressure on pump.
Description of water-valves: Metallic; seats, rubber.
Kind of power used: Steam.
Description of boilers: Two, 11 feet long, 40 inches diameter; fuel, soft coal.
Description of engine: Simple; cylinder, 12 inches diameter, 150 strokes per minute.
Cost of engine and pump: $1,500.

POTSDAM:

Population: 2,762 inhabitants.
Style of corporation: Municipal.
Water obtained from: Rocket river.
Character and dimensions of dams: Two, wooden; 100 feet long each.
Water first introduced: In 1871.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 78 feet (average).
Total length of distributing mains: About 2 miles.
Number of water-takers: 198.
Consumption of water: 30 gallons per head per day (estimated).
First cost of water-works: $50,000.
Average annual cost of maintenance and repairs: $325.
Filtering apparatus: Wooden well, about 20 feet square; small stone and gravel; cleaned three times a year.
Number of fire-plugs: 33.
Design and dimensions of pump and water-plunger: Built by Holly Manufacturing Company, Lockport, New York, in 1871; size No. 6; 30 revolutions per minute; pump-barrel, 12 by 14 inches; head, 78 feet (average) on pump.
Time pump is run: Constantly.
Time spent in repairs: About 200 hours per year.
Description of water-valves: Flap; size, 9 inches; lift, 90°.
Kind of power used: Water.
Description of water-wheels: One Holly turbine, 7 feet diameter, drawing 1,300 inches water; one American turbine, 48 inches diameter, drawing 336 inches water; about 9 feet head.
Cost of engines and pump: $10,000.

SARATOGA SPRINGS:

Population: 8,421 inhabitants.
Style of corporation: Municipal.
Water obtained from: Creek and springs.
Area and capacity of reservoir: Lake, 108 acres; average depth, 18 feet.
Cost of dam: About $26,000.
Water first introduced: July, 1871.
Description of main conduit: 580 feet long, 3 feet diameter, brick; 300 feet long, wood; head, 8 feet.
Sizes of distributing mains; 12 to 3 inches.
Available head: 62 to 172 feet; water-supply deficient.

SARATOGA SPRINGS—Continued.

Total length of distributing mains: $17\frac{1036}{5280}$ miles.
Number of water-takers: 1,346.
Consumption of water: 117 gallons per head per day (exact).
First cost of water-works: $250,000.
Average annual cost of maintenance and repairs: $7,358 07.
Number of fire-plugs: 133.
Design and dimensions of pump and water-plunger: Built by Holly Manufacturing Company, Lockport, New York, in 1870–'71; plain piston-plunger; square rubber packing; 8 to 20 strokes per minute; pump-barrel, 10 by 24 inches.
Time pump is run: Constantly.
Description of force-main: 2,678 feet long, 12 inches diameter, 172 to 184 feet head on pump.
Description of water-valves: Leather hinge, iron shod; 9 by $3\frac{1}{2}$ inches size, $1\frac{1}{4}$ inch lift.
Kind of power used: Steam and water.
Description of water-wheels: Two Leffel turbines, 36 and 6 inches diameter, 30 feet head.
Description of boilers: One double return-flue, one marine and one upright flue; fuel, Scranton grate coal.
Description of engine: Condensing or high-pressure, at will, 14 inches diameter, 24 inches stroke, 20 to 50 strokes per minute; balanced lift-valve, worked by cams, governed by water in pipes; 2 air-pumps, 10 inches diameter, 14 inches stroke; jet-condenser.
Cost of engine and pump: $46,000.
Duty of engine: 48,000,000 to 50,000,000 foot-pounds daily.
Remark: The advantage of pumping direct into mains is economy.—In hot weather a green vegetable growth pollutes the water.

SCHENECTADY:

Population: 13,655 inhabitants.
Name of corporation: Schenectady Water Company (private).
Water obtained from: Mohawk river.
Character and dimensions of dam: 20 feet from river, 114 feet long, 10 feet wide, 18 feet deep, arched with brick to keep out surface-water.
Water first introduced: September, 1872.
Description of main conduit: 11 miles long, 12, 10, 8, 6, and 4 inches diameter; head, 140 feet (average).
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 60 to 80 pounds.
Total length of distributing mains: 11 miles.
Number of water-takers: 411.
Consumption of water: 60 gallons per head per day (estimated).
First cost of water-works: $115,000.
Average annual cost of maintenance and repairs: $7,000.
Filtering apparatus: Well, 114 by 6 feet; coarse sand and gravel.
Number of fire-plugs: 123.
Design and dimensions of pumps and water-plungers: Six, built by Holly Manufacturing Company, Lockport, New York; 12 inches diameter, 12 inches stroke, 12 to 20 strokes per minute; pump-barrel, 12 by 12 inches.
Time pumps are run: Constantly.
Description of force-main: 11 miles long, 75 pounds pressure on pumps.
Description of water-valves: Brass; 7 by 4 inches size, $2\frac{1}{2}$ inches lift.
Kind of power used: Steam.
Description of boilers: One upright flue, one locomotive, 150 horse-power each; fuel, anthracite coal.
Description of engine: Condensing or non-condensing; 16 by 24 inches, 15 to 25 strokes per minute; plain D-valves, automatic cut-off.
Cost of engine and pumps: $30,000.

OHIO.

DAYTON:

Population: 38,678 inhabitants.
Name of corporation: Dayton City Water-Works (municipal).

DAYTON—Continued.

Water obtained from: Wells.
Water first introduced: In 1870.
Sizes of distributing mains: 20, 16, 12, 10, 8, 6, 4, 3, and 2 inches.
Total length of distributing mains: $32\frac{2615}{5280}$ miles.
Consumption of water: About 1,000,000 gallons per day (estimated).
First cost of water-works: $555,000.
Average annual cost of maintenance and repairs: $16,000.
Filtering system: A tunnel 300 feet long, 26 feet below surface of ground.
Number of fire-plugs: 281.
Design and dimensions of pumps and water-plungers: Made by Holly, in 1870; pump-barrels, 12 by 27 inches.
Description of force-main: 4,416 feet long, 20 inches diameter, and 100 feet long, 12 inches diameter; 50 pounds pressure on pumps.
Kind of power used: Steam.

IRONTON:

Population: 8,857 inhabitants.
Name of corporation: City Water-Works (municipal).
Water obtained from: Ohio river.
Water first introduced: July, 1873.
Sizes of distributing mains: 12 to 4 inches.
Available head: 30 pounds (average).
Total length of distributing mains: About 8 miles.
Number of water-takers: 850.
Consumption of water: 650,000 gallons per day (estimated).
First cost of water-works: $175,000.
Number of fire-plugs: 114.
Design and dimensions of pump and water-plungers: Six bucket-plungers, 14 inches diameter, 14 inches stroke, 10 strokes per minute; pump-barrels, 14 inches diameter.
Time pump is run: Constantly.
Description of water-valves: Rubber, 12 inches, 1 inch lift.
Kind of power used: Steam.
Description of boilers: Tubular, 15 feet long, 5 feet diameter; fuel, bituminous coal.
Description of engines: Two non-condensing, 14 inches diameter, 24 inches stroke, 30 strokes per minute; slide-valve with cut-off.
Cost of engines and pump: $35,000.
Duty of engines: 2,000,000 gallons in 24 hours guaranteed.
Remarks: The disadvantage of pumping direct into main is muddy water sometimes; the river brings down leaves and drift-wood, which are an annoyance in pumping.

MANSFIELD:

Population: 9,859 inhabitants.
Name of corporation: Mansfield Water-Works (municipal).
Water obtained from: Springs.
Water first introduced: August, 1872.
Sizes of distributing mains: 14, 12, 8, 6, 5, and 4 inches.
Available head: 80 pounds (average).
Total length of distributing mains: 15 miles.
Number of water-takers: 550.
Consumption of water: 500,000 gallons per day (estimated).
First cost of water-works: $175,000.
Average annual cost of maintenance and repairs: $7,500.
Number of fire-plugs: 100.
Design and dimensions of pump and water-plungers: Built by Holly Manufacturing Company, Lockport, New York, in 1872.
Time pump is run: Constantly.
Description of force-main: 2,868 feet long, 14 inches diameter, 80 pounds pressure on pump.
Description of water-valves: Leather, 4 by 11 inches, $1\frac{1}{2}$ inch lift.
Kind of power used: Steam.
Description of boilers: Three; 12 feet long, 60 inches diameter, 60 pounds pressure; fuel, slack coal; one boiler used at a time.

MANSFIELD—Continued.

Description of engine: Condensing and non-condensing; 2 cylinders, 14 inches diameter, 24 inches stroke, 24 strokes per minute; slide-valve, puppet cut-off.

Cost of engine and pump: $32,000.

Remarks: The advantage of pumping direct into mains is great pressure for fire purposes.

NORWALK:

Population: 5,704 inhabitants.

Name of corporation: Norwalk Water-Works (municipal).

Water obtained from: Huron river.

Character and dimensions of dam: Stone, 55 feet long; bottom 13 feet wide, top 2 feet 6 inches wide; laid in Portland cement; top stones clapped with 1½ inch square iron.

Cost of dam: $3,400.

Water first introduced: In 1870.

Description of main conduit: 3½ miles long; diameters, 10, 8, 6, 4, and 3 inches; cast iron; 75 pounds pressure (average).

Sizes of distributing mains: 10 to 3 inches.

Available head: 70 pounds (average).

Total length of distributing mains: 11 miles.

Number of water-takers: 360.

Consumption of water: 400,000 gallons per day (estimated).

First cost of water-works: $100,000.

Average annual cost of maintenance and repairs: $4,800.

Number of fire-plugs: 94.

Design and dimensions of pump and water-plungers: Built by Worthington, New York; four plain plungers, 25 by 14 inches and 15 by 12 inches; 28 strokes per minute; pump-barrel, 62 inches long, 14 inches diameter.

Time pump is run: Constantly.

Description of force-main: 200 feet long, 173 pounds pressure on pump.

Description of water-valves: Rubber, 6 inches diameter, 1½ inch lift.

Kind of power used: Steam.

Description of boilers: Holly, 16 feet long, 5 feet diameter, 44 pounds pressure; fuel, Massillon coal.

Description of engines: Condensing, compound, double; low-pressure cylinder, 33⅜ inches diameter, high-pressure cylinder, 19¼ inches diameter; 25 inches stroke each, 28 strokes per minute; slide-valves; Worthington air-pumps and condenser.

Cost of pump and engines: $13,000.

Duty of engines: 41,186,345 foot-pounds daily.

Remarks: The disadvantage of pumping direct into mains is non-uniformity of pressure.—Impurities are caused by rain washing banks of river, making water muddy.

PORTSMOUTH:

Population: 11,321 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Ohio river.

Water first introduced: In 1871.

Discharging capacity of conduit: 650 gallons per minute.

Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.

Available head: 40 pounds (average).

Design and dimensions of pumps and water-plungers: Built by Holly Manufacturing Company, Lockport, New York, in 1871; six plain plungers, 14 inches diameter, 24 inches stroke, 12 strokes per minute; pump-barrel, 14 by 24 inches.

Time pumps are run: Constantly.

Description of force-main: 40 pounds pressure on pumps.

Description of water-valves: Leather, 2½ by 5 inches in size, 2 inches lift.

Kind of power used: Steam.

Description of boilers: 18 feet long, 60 inches diameter; 67 tubes, 3¼ inches diameter; fuel, soft Ohio River coal.

Description of engines: Non-condensing; two cylinders, 14 inches diameter, 24 inches stroke; one rotary engine, 20 inches diameter, 15 inches stroke; piston-head; two pumps for fire, 20 by 8 inches, 25 strokes per minute; slide-valves worked by eccentric, with balance cut-off.

SIDNEY:

Population: 3,823 inhabitants.

Style of corporation: Municipal.

Water obtained from: Mosquito creek.

Water first introduced: October, 1873.

Sizes of distributing mains: 12, 9, and 6 inches.

Available head: 175 pounds (average).

Total length of distributing mains: 3 miles.

Number of water-takers: 100.

First cost of water-works: $56,000.

Average annual cost of maintenance and repairs: $1,400.

Number of fire-plugs: 38.

Design of pump and water-plunger: Built by the Holly Manufacturing Company, Lockport, New York.

Time pump is run: 18 hours per day.

Time spent in repairs: 1 week per year.

Kind of power used: Water.

Description of water-wheels: Two; Holly patent, 29 feet fall.

Remarks: The disadvantage of pumping direct into mains is that the pressure on the pipes is too uneven.—Water is muddy after rains.

URBANA:

Population: 6,252 inhabitants.

Name of corporation: Urbana Water-Works Company (private).

Water obtained from: Well.

Area and capacity of reservoir: Well, 20 feet diameter, 20 feet deep.

Water first introduced: February, 1878.

Sizes of distributing mains: 14 to 4 inches.

Available head: 125 feet (average).

Total length of distributing mains: 9 miles.

Number of water-takers: 253.

Consumption of water: 260,000 gallons per day (estimated).

Average annual cost of maintenance and repairs: $2 90.

Number of fire-plugs: 73.

Design and dimensions of pump and water-plungers: Built by Holly Manufacturing Company, Lockport, New York, in 1877; piston-plungers, 7⅓ inches diameter, 2 feet stroke, 24 strokes per minute; pump-barrel, 7½ inches diameter.

Time pump is run: Constantly.

Time spent in repairs: None.

Description of force-main: 9 miles long, 45 pounds pressure on pump.

Description of water-valves: Brass hinge, 8 by 4 inches, ⅝ inch lift.

Kind of power used: Steam.

Description of boilers: Return-flue, 16 feet long, 5 feet diameter, 50 pounds pressure; 14¼ pounds water to 1 pound coal; fuel, bituminous coal.

Description of engine: Compound condensing, 12 inches diameter, 2 feet stroke; 4 cylinders; 24 strokes per minute; slide-valve operated by eccentric; air-pump piston, with rubber valve; jet-condenser.

Cost of pump and engine: $20,000.

Duty of engine: 30,080,555 foot-pounds; 900 pounds coal to 8,260,000 gallons daily.

YOUNGSTOWN:

Population: 15,435 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Mahoning river.

Water first introduced: In 1871.

Sizes of distributing mains: 15, 12, 8, 6, and 4 inches.

Available head: 70 to 80 pounds.

Total length of distributing mains: 11 miles.

Number of water-takers: 840.

Consumption of water: 1,500,000 gallons per day (estimated).

First cost of water-works: $150,000.

Average annual cost of maintenance and repairs: $7,500

Number of fire-plugs: 105.

YOUNGSTOWN—Continued.

Design and dimensions of pump and water-plunger: Built by H. R. Worthington, New York; pump-barrel, 17½ by 36 inches.
Time pump is run: Constantly.
Kind of power used: Steam.
Description of boilers: Three tubular; one 16 feet long, 6 feet diameter; two small upright drop-tubes; fuel, bituminous coal.
Description of engine: Non-expanding condensing; Worthington valves; air-pump and condenser.
Cost of engine and pump: $10,000.

OREGON.

ALBANY:

Population: 1,867 inhabitants.
Name of corporation: Crawford & Foster (private).
Water obtained from: Santian canal and Calapoosa river.
Water first introduced: July, 1880.
Sizes of distributing mains: 6, 4, 3, and 2 inches.
Available head: 100 feet (average).
Total length of distributing mains: About 3 miles.
First cost of water-works: About $20,000.
Number of fire-plugs: 2.
Design and dimensions of pumps and water-plungers: Built by S. H. Moore, Portland, Oregon; two pumps, 24 by 12 inches, 12 to 24 strokes per minute; pump-barrel, 12 by 24 inches.
Time pumps are run: Constantly.
Description of force-mains: A tank 75 feet high; 45 pounds pressure on pumps.
Kind of power used: Water.
Description of water-wheels: One Burnham and one Leffel; 24 feet head.

PENNSYLVANIA.

DANVILLE:

Population: 8,346 inhabitants.
Name of corporation: Danville Water-Works (municipal).
Water obtained from: Well on river-bank.
Area and capacity of reservoir: 50 feet long, 7½ feet wide, 10 feet deep.
Cost of dam: $4,000.
Water first introduced: In 1872.
Sizes of distributing mains: 12, 8, 6, and 4 inches.
Available head: 65 pounds (average).
Number of water-takers: 800.
First cost of water-works: $125,000.
Average annual cost of maintenance and repairs: $4,000.
Filtering system: Gravel and sand.
Number of fire-plugs: 97.
Design and dimensions of pumps and water-plungers: Built by the Holly Manufacturing Company, Lockport, New York; six plain plungers 14 inches diameter, and six 18 inches diameter two rotary, capacity 316,800 gallons, 10 strokes per minute.
Kind of power used: Steam.
Description of boilers: One horizontal, 18 feet long, 5 feet diameter; one upright, 20 feet high, 7 feet diameter.
Description of engines: One double, 150 horse-power; one rotary, 200 horse-power.
Cost of engines and pumps: $36,000.
Remarks: The advantage of pumping direct into mains is marked control of pressure.

TITUSVILLE:

Population: 9,046 inhabitants.
Name of corporation: City Water-Works (municipal).
Water obtained from: Dug well.
Water first introduced: January, 1873.
Sizes of distributing mains: 15, 12, 8, 6, 4, and 2 inches.
Available head: 40 pounds (average).
Total length of distributing mains: 9½ miles.

TITUSVILLE—Continued.

Number of water-takers: 720.
Consumption of water: 400,000 gallons per day (estimated).
First cost of water-works: $139,000.
Average annual cost of maintenance and repairs: $7,000.
Number of fire-plugs: 63.
Design and dimensions of pump and water-plunger: Holly; 20 strokes per minute.
Time pump is run: Constantly.
Kind of power used: Steam.
Description of boilers: Two 40 horse-power flue; fuel, slack and nut bituminous coal.
Cost of engine and pump: $30,000.

VIRGINIA.

NORFOLK:

Population: 21,966 inhabitants.
Name of corporation: City Water-Works (municipal).
Water obtained from: Springs and lake Lawson.
Total area of water-shed available: 500 acres.
Capacity of reservoirs: One lake, 470,000,000 gallons; Lawson, 120,000,000 gallons; Morris, 40,000,000 gallons.
Character and dimensions of dams: All puddled clay.
Cost of dams: $500,000.
Water first introduced: In July, 1873.
Description of main conduit: 4.6 miles long, 12 inches diameter; cast iron.
Discharging capacity: 900,000 gallons per day, 40 pounds pressure (average).
Description of settling reservoirs: Two; one, capacity 5,000,000 gallons, and one, capacity 3,000,000 gallons; water is pumped into these from lake Lawson and thence into mains.
Sizes of distributing mains: 10, 8, 6, 4, 3, and 2 inches.
Available head: 40 pounds (average).
Total length of distributing mains: 22 miles.
Consumption of water: 70 gallons per head (estimated).
Number of water-takers: 2,100.
First cost of water-works: $450,000.
Average annual cost of maintenance and repairs: $12,000 to $13,000.
Filtering system: Use settling reservoirs.
Number of fire-plugs: 95.
Design and dimensions of pumps and water-plungers: One set Holly and two Worthington; plain plungers; two 14 inches diameter, 24 inches stroke; two 14 inches diameter, 26 inches stroke.
Time pumps are run: Constantly.
Description of force-main: 4.6 miles long, 12 inches diameter, 45 pounds pressure on pumps.
Description of water-valves: Rubber disks, 6 inches diameter, ¾ inch lift.
Kind of power used: Steam.
Description of boilers: Two; fuel, Georgia Creek coal.
Description of engines: One Worthington compound and one high-pressure, 44 strokes per minute; slide-valves operated by connecting-rod and rock-shaft; one set Holly pumps.
Cost of engines and pumps: $50,000.
Remarks: The advantage of pumping direct into mains is the perfect control of pressure for fire service.

WEST VIRGINIA.

MARTINSBURG:

Population: 6,335 inhabitants.
Style of corporation: Municipal.
Water obtained from: Springs.
Water first introduced: In 1873.
Sizes of distributing mains: 12 to 1½ inches.
Available head: 30 pounds (average).
Total length of distributing mains: About 6 miles.
Number of water-takers: 480.
Consumption of water: 200,000 gallons per day (estimated).
First cost of water-works: About $80,000.

MARTINSBURG—Continued.

Average annual cost of maintenance and repairs: $1,200.

Number of fire-plugs: 42.

Design and dimensions of pumps and water-plungers: Built by the Holly Manufacturing Company, Lockport, New York; four double-acting piston, 7½ inches bore, 22 inches stroke.

Time pumps are run: Constantly.

Description of force-main: 4½ miles long, 60 pounds pressure on pumps.

Description of water-valves: Leather, 3 by 6 inches.

Kind of power used: Steam and water.

Description of water-valves: Two American turbine; one 30 inches and one 54 inches diameter; made by Stout, Mills, & Temple, Dayton, Ohio; 10 feet head.

Description of boiler: Horizontal, 16 feet long, 60 inches diameter; 54 tubes, 3½ inches diameter.

Description of engine: Condensing or non-condensing, 16 by 27 inches; puppet-valve, operated by cams; plain air-pump, 14 by 24 inches.

Cost of engine and pumps: $30,000.

WISCONSIN.

BLACK RIVER FALLS:

Population: 1,427 inhabitants.

Style of corporation: Municipal.

Water obtained from: Black river.

Character and dimensions of dam: One across Black river, at head of falls, made of brush and stone; head obtained, 11 feet.

Water first introduced: In 1875.

Size of distributing mains: 6 inches.

First cost of water-works: About $6,000.

Average annual cost of maintenance and repairs: $125.

Number of fire-plugs: 6.

BLACK RIVER FALLS—Continued.

Design and dimensions of pump and water-plunger: Rotary, Johnson's patent, built by B. F. Babbitt, Utica, New York; 350 revolutions per minute; pump-barrel, 12 inches diameter.

Description of force-main: 100 feet long, 6 inches diameter; head, 12 feet on pump.

Kind of power used: Water.

Description of water-wheels: Two turbines, 60 inches diameter, Houston patent, Racine, Wisconsin, 11 feet head, 115 revolutions per minute.

LA CROSSE:

Population: 14,505 inhabitants.

Style of corporation: Municipal.

Water obtained from: Mississippi river.

Water first introduced: In 1877.

Sizes of distributing mains: 16, 12, 8, and 6 inches.

Available head: 40 pounds (average).

Total length of distributing mains: 8½ miles.

Number of water-takers: 325.

First cost of water-works: $90,000.

Number of fire-plugs: 90.

Design and dimensions of pumps and water-plungers: Duplex, built by G. F. Blake Manufacturing Company, Boston, Massachusetts, 30 inches steam, 16 inches water, 2 feet stroke each; pump-barrel, 16 inches diameter.

Time pumps are run: Constantly.

Kind of power used: Steam.

Description of boilers: Two; 16 feet long, 5 feet diameter; fuel, pine slabs.

Description of engine: Simple, high-pressure; cylinder, 30 inches diameter, 24 inches stroke.

Cost of engine and pumps: $10,000.

Remarks: The advantage of pumping direct into mains is cheapness; the disadvantage, non-uniformity of pressure.

WATER-WORKS EMPLOYING THE GRAVITY SYSTEM AND PUMPING TO DISTRIBUTING RESERVOIR.

CALIFORNIA.

SAN FRANCISCO:

Population: 233,959 inhabitants.

Name of corporation: Spring Valley Water-Works (private).

Total area of water-shed available: 28 square miles.

Capacity of receiving reservoirs: Pilarcitos, 140,000,000 cubic feet; San Andres, 1,930,000,000 cubic feet; Crystal Springs, 1,200,000,000 cubic feet.

Character and dimensions of dams: Pilarcitos, 95 feet high, 600 feet long, 25 wide on top; water-slope, 2½ to 1; dry-slope, 3 to 1. San Andres, 95 feet high, 640 long, 25 feet wide on top; water-slope, 3½ to 1; dry-slope, 3 to 1. Crystal Springs, 80 feet high, 500 feet long, 30 feet wide on top; water-slope, 3½ to 1; dry-slope, 3 to 1.

Water first introduced: In 1858.

Description of main conduits: Pilarcitos, 7,840 feet long, 3 feet 6 inches by 4 feet 6 inches cross-section, oval, brick masonry; also 16 miles long, 30 inches diameter, tarred wrought iron. San Andres, 3,050 feet long; 3 feet 6 inches by 4 feet 6 inches cross-section, oval, brick masonry; also 12 miles long, 30 inches diameter, tarred wrought iron. Labos creek, 3,000 feet long, 3½ by 4 feet cross-section, brick; also 8,900 feet long, 24 inches diameter, cement pipe; also 2 miles redwood flue, 22 inches to 19 inches.

Discharging capacity: Pilarcitos, 11,000,000 gallons per day; head, 375 feet (average). San Andres, 9,500,000 gallons per day; head, 250 feet (average). Labos creek, 2,000,000 gallons per day; head, 290 feet (average).

Description of distributing reservoirs: Lake Hunda, heavy masonry work; capacity, 35,000,000 gallons; elevation, 377 feet. College Hill, capacity, 14,000,000 gallons; elevation, 252 feet. Market street, capacity, 2,250,000 gallons; elevation, 200 feet. Upper Russian Hill, capacity, 4,500,000 gallons; elevation, 295 feet. Lower Russian Hill, capacity, 6,000,000 gallons; elevation, 148 feet. Clay Street Hill tank, capacity, 140,000 gallons; elevation, 365 feet.

Sizes of distributing mains: 22 to 3 inches.

Available head: 50 to 100 pounds.

Total length of distributing mains: 175 miles.

Number of water-takers: 20,500.

Consumption of water: 62.5 gallons per head per day (estimated).

Number of fire-plugs: 1,350.

Design and dimensions of pumps and water-plungers: Built by Pacific Iron Works and Vulcan Iron Works, San Francisco, in 1858 and 1862; Risdon Iron Works, San Francisco, in 1877; plain plungers, 6 to 18 strokes per minute; pump-barrels, L. C. 2 P., 14 inches diameter, 7 feet stroke; C. S. 2 P., 12 inches diameter, 5 feet stroke; L. M. 2 P., 20 inches diameter, 6 feet stroke.

Time pumps are run: Lobos Creek, constantly; balance stopped.

Time spent in repairs: 1 day per year.

Description of force-mains: Lobos Creek, 60 pounds pressure on pumps; on two, 150 pounds pressure; Crystal Spring, 190 pounds pressure; L. M., 130 pounds pressure.

SAN FRANCISCO—Continued.

Description of water-valves: Crystal Spring and L. M., double-beat crown.

Kind of power used: Steam.

Description of boilers: Lobos Creek, 4 tubular, 16 feet long, 42 inches diameter; tubes, 3 inches diameter; evaporation, Mount Diablo coal, 5 to 1, and for anthracite, 10¾ to 1.

Description of engines: Lobos Creek, condensing; cylinder, 40 inches diameter, 48 inches stroke; Crystal Spring, distinct acting compound condensing; L. M., direct compound condensing, 30 strokes per minute; Lobos Creek, ordinary lift-valve with screw; air-pump, 30 by 24 inches; jet-condenser, 24 by 36 inches.

Duty of engines: Lobos Creek, with anthracite coal, 50,000,000 foot-pounds daily; with Mount Diablo coal, 4,000,000 foot-pounds daily.

VALLEJO:

Population: 5,987 inhabitants.

Name of corporation: Vallejo City Water Company (private).

Water obtained from: Surface-water.

Total area of water-shed available: About 100 square miles.

Capacity of reservoir: 500,000,000 gallons.

Character and dimensions of dam: 35 feet long, 40 feet high 150 feet base; built in sections; dirt and clay; best material in front section; stone rubbish and coarse material in back section.

Cost of dam: $40,000.

Water first introduced: In 1871.

Description of main conduit: 3½ miles long, 12 inches diameter; cast iron.

Description of distributing reservoir: Situated at an elevation of 150 feet above tide-water.

Sizes of distributing mains: 12, 6, 4, and 2 inches.

Total length of distributing mains: About 18 miles.

Number of water-takers: About 1,000.

Consumption of water: 100,000 gallons per day (estimated).

First cost of water-works: $200,000.

Number of fire-plugs: 35.

Design and dimensions of pump and water-plunger: Hooker, built by W. F. Garrett, San Francisco; plain No. 8 plunger, 16 inches stroke, 100 strokes per minute; pump-barrel, 6 by 18 inches.

Time pump is run: 12 hours per day in summer and 6 hours per day in winter.

Description of force-main: 3½ miles long.

Description of water-valves: Rubber, 6 inches diameter.

Kind of power used: Steam.

Description of boiler: 60 horse-power, 40 pounds pressure.

Cost of pump: $700.

COLORADO.

LEADVILLE:

Population: 14,820 inhabitants.

Name of corporation: Leadville Water Company (private).

Water obtained from: Stream in Big Evans gulch.

Total area of water-shed available: About 6 square miles.

Dimensions of dam: 200 by 300 feet, 12 feet deep (average).

LEADVILLE—Continued.

Cost of dam: $100,000.
Water first introduced: March, 1879.
Description of main conduit: 75,639 feet long, 6 and 8 inches diameter; cast iron.
Discharging capacity: About 16,000 gallons per hour; head, 190 feet (average).
Description of distributing reservoir: 40 by 20 feet, 16 feet deep; it is covered; capacity, 96,000 gallons.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 165 feet (average).
Total length of distributing mains: 4¾ miles.
Number of water-takers: About 300.
Consumption of water: 100,000 gallons per day (estimated).
First cost of water-works: $77,000.
Average annual cost of maintenance and repairs: $12,000.
Number of fire-plugs: 47.
Design of pumps and water-plungers: Knowles' patent.

ILLINOIS.

OREGON:

Population: 1,088 inhabitants.
Style of corporation: Municipal.
Water obtained from: Rock river.
Capacity of reservoir: Over 1,000,000 gallons.
Character and dimensions of dam: Across Rock river; made for running mills, etc.
Cost of dam: Dam, $75,000; reservoir, $14,000.
Water first introduced: November, 1879.
Description of main conduit: 35,000 feet long, 8 inches diameter; iron.
Discharging capacity: 31,500 gallons per hour; head, 200 feet (average).
Description of distributing reservoir: Circular; diameter, 150 feet, 13 feet deep.
Sizes of distributing mains: 8 and 6 inches.
Available head: 200 feet (average).
Total length of distributing mains: 1½ mile.
Number of water-takers: 25.
First cost of water-works: $14,000.
Average annual cost of maintenance and repairs: $200.
Number of fire-plugs: 13.
Design and dimensions of pump and water-plungers: Built by the Blake Manufacturing Company; plain plungers, 6 inches diameter, 8 inches stroke, 90 strokes per minute; pump-barrels, 8 by 6 inches.
Time pump is run: 6 days per month.
Time spent in repairs: About 20 hours per year.
Description of force-main: 2,500 feet long, 8 inches diameter, 95 pounds pressure on pump.
Description of water-valves: Puppet, 3 inches diameter, 3½ inches lift.
Kind of power used: Steam.
Description of boiler: One tubular, 12 feet long, 40 inches diameter, 60 pounds pressure.
Description of engine: Non-condensing, 90 strokes per minute; slide-valves.
Cost of engine and pump: $800.

IOWA.

MUSCATINE:

Population: 8,295 inhabitants.
Name of corporation: Muscatine Water-Works Company (private).
Water obtained from: Mississippi river.
Capacity of reservoir: 1,500,000 gallons.
Cost of dam: $11,000.
Water first introduced: In 1876.
Description of main conduit: 700 feet long, 18 inches diameter; iron.

MUSCATINE—Continued.

Description of distributing reservoir: Puddled and faced with two thicknesses of brick laid in cement; discharge-pipe enters at bottom; depth of water, 20 feet; overflow 2 feet from top.
Sizes of distributing mains: 12, 10, and 6 inches.
Available head: 180 feet (average).
Total length of distributing mains: 4½ miles.
Number of water-takers: 300.
Consumption of water: 200,000 gallons per day (estimated).
First cost of water-works: $62,000.
Average annual cost of maintenance and repairs: $3,500.
Number of fire-plugs: 42.
Design and dimensions of pump and water-plungers: Built by Cope & Maxwell, Hamilton, Ohio; two plain plungers, 10 inches diameter, 36 inches stroke, 25 strokes per minute; pump-barrels, 10 by 30 inches.
Time pump is run: 4 days per week.
Description of force-main: ½ mile long, 10 inches diameter, 80 pounds pressure on pump.
Description of water-valves: Rubber, 8 inches, 1 inch lift.
Kind of power used: Steam.
Description of boilers: Tubular, 12 feet long, 48 inches diameter; flues, 3 inches diameter, 80 pounds pressure.
Description of engine: Non-condensing; cylinder, 18 inches diameter, 36 inches stroke, 20 to 35 strokes per minute; combination and slide-valves.
Cost of engine and pump: $8,000.

MARYLAND.

BALTIMORE:

Population: 332,313 inhabitants.
Name of corporation: City Water-Works (municipal).
Water obtained from: Jones' falls and Gunpowder river.
Area and capacity of reservoirs: Jones' Falls supply, 116 acres, 400,000,000 gallons; Gunpowder River supply, 252 acres, 510,000,000 gallons.
Character and dimensions of dams: Lake Roland, rubble and cut stone on rock, backed with clay, 330 feet long; thickness of masonry at foundation of overfall, 60 feet. Loch Raven, built same, 556 feet long; thickness of masonry at foundation of overfall, 62 feet. Both 30 feet high, backed with 50 feet of clay at foundation.
Cost of dams: Lake Roland, $152,000; Loch Raven, $250,000; reservoirs cost $2,695,000.
Water first introduced: In 1870.
Description of main conduits: Jones' falls, 3.8 miles long, oval, 5 feet wide, 6⅓ feet high, area, 24¾ square feet; built of stone and brick masonry; fall, 1 foot per mile. Gunpowder, a tunnel, 7 miles long, 2 miles arched with brick, 5 miles through solid rock; circular; diameter, 12 feet; fall, same as the other.
Discharging capacity: Jones' falls, 36,000,000 gallons per day; head, 5 feet. Gunpowder, 170,000,000 gallons per day; head, 7 feet.
Description of distributing reservoirs: Various forms; earth and clay, lined on each side with stone; outside slopes all 2 to 1; inside slopes, 1½ to 1, 3 to 1, and 4 to 1; puddled cores in all embankments going below bottom of basin and running well up into excavation on the sides; width of embankment, 15 feet; for lakes, 60 and 80 feet.
Sizes of distributing mains: 40 to 3 inches.
Available head: Water-supply slightly deficient at dividing line of service.
Total length of distributing mains: 278 miles.
Number of water-takers: 48,669.
Consumption of water: 45 gallons per head per day (estimated).
First cost of water-works: Purchased from old water company for $3,500,000.
Average annual cost of maintenance and repairs: $3,500.

BALTIMORE—Continued.

Number of fire-plugs: 825.

Design and dimensions of pumps and water-plungers: Built by H. R. Worthington, Brooklyn, New York; plain plungers, duplex; two sets, 17½ inches diameter, 36 inches stroke; two sets, 22 inches diameter, 48 inches stroke; 24 strokes per minute.

Time pumps are run: Two sets 98 days per year; two sets 60 days per year.

Time spent in repairs: Two sets 50 hours per year, and two sets 75 hours per year.

Description of force-mains: 6,100 feet long, 60 pounds pressure on pumps; 3½ miles long, 85 pounds pressure on pumps.

Description of water-valves: Worthington gum disks.

Kind of power used: Steam.

Description of boilers: Horizontal tubular, 45 pounds pressure; fuel, bituminous and semi-bituminous coal.

Description of engines: Worthington compound duplex, 24 strokes per minute; slide-valves operated by opposite engine; lifting-pump cylinder-condenser.

Cost of engines and pumps: Two sets $46,000; two sets $85,000.

MASSACHUSETTS.

CHELSEA:

Population: 21,782.

Supplied by Boston water-works.

DORCHESTER:

Population: (Included in Boston.)

Supplied by Boston water-works.

HAVERHILL:

Population: 18,472 inhabitants.

Name of corporation: Haverhill Aqueduct Company (private).

Water obtained from: Kenoga, Saltonstall, and Pentucket lakes.

Water first introduced: In 1802.

Description of main conduit: 16, 12, and 10 inches diameter; wrought iron and cement; head, 256 feet (average).

Description of distributing reservoir: Wrought iron, 40 feet high, 30 feet diameter, with stand-pipe in center 50 feet high, 24 inches diameter.

Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.

Available head: 150 feet (average).

Total length of distributing mains: About 25 miles.

Number of water-takers: About 2,000.

Consumption of water: 100 gallons per head per day (estimated).

First cost of water-works: $350,000.

Average annual cost of maintenance and repairs: $8,000.

Number of fire-plugs: 20; 63 hydrants.

Design and dimensions of pumps and water-plungers: Built by H. R. Worthington, New York, in 1879; two, compound duplex; capacity, 2,000,000 gallons per day.

Time pumps are run: One, 12 hours per day.

Description of force-main: 3,000 feet long 16 inches diameter; head, 156 feet on pumps.

Kind of power used: Steam.

Description of boiler: Horizontal tubular, 60 horse-power; fuel, hard coal.

Description of engine: Worthington, compound duplex.

Cost of engine and pumps: $25,000.

NEW JERSEY.

BURLINGTON:

Population: 6,090 inhabitants.

Style of corporation: Municipal.

Water obtained from: Delaware river mainly.

Capacity of reservoir: 90,000 gallons.

Water first introduced: In 1804.

BURLINGTON—Continued.

Description of distributing reservoirs: Eight, iron; seven of them 7 feet diameter, 9 feet high; one, 20 feet diameter, 25 feet high; inclosed in building for the purpose.

Sizes of distributing mains: 24, 16, 12, 10, 8, 6, and 4 inches.

Available head: 50 feet (average).

Total length of distributing mains: 9 miles.

Number of water-takers: 1,027.

Consumption of water: 140,000 gallons per day (exact).

First cost of water-works: $60,000.

Average annual cost of maintenance and repairs: $2,500.

Number of fire-plugs: 84.

Design and dimensions of pumps and water-plungers: Old, unknown; new, built by Worthington, New York, in 1878; two plain plungers, 10 inches diameter, 18½ inches stroke, 45 strokes per minute (average).

Time pumps are run: 6 hours per day.

Description of force-main: 12 inches diameter, 22 pounds pressure on pumps.

Description of water-valves: Gum, circular.

Kind of power used: Steam.

Description of boilers: Tubular, 40 horse-power, 50 pounds pressure; fuel, anthracite coal.

Description of engines: Compound condensing; high-pressure cylinder, 10 inches diameter; low-pressure cylinder, 24 inches diameter; 18½ inches stroke, 45 strokes per minute; ordinary slide-valves, worked by opposite engine; air-pump at end of pump on low-pressure side, same capacity as water-pump; condenser, 12 inches diameter, 3 feet high.

Cost of engines and pumps: About $5,200.

Remarks: The advantage of pumping to reservoir consists in this, that it gives security in case of fire.—Generally water is pure. In summer spongy fungus is sometimes found in the mains.

NEWARK:

Population: 136,508 inhabitants.

Name of corporation: The Newark Aqueduct Company (municipal).

Water obtained from: Passaic river at Belleville.

Total area of available water-shed: 981 square miles.

Cost of dams: $2,671,580 40.

Description of main conduit: 3 miles long, 30 inches diameter; iron; head, 165 feet (average).

Description of distributing reservoir: Surface elevation, 114 feet above tide-water; capacity, 22,000,000 gallons.

Sizes of distributing mains: 20 to 3 inches.

Available head: 114 feet (average); water-supply deficient.

Total length of distributing mains: 136 miles.

Number of water-takers: 11,000.

Consumption of water: 9,386,000 gallons per year (estimated).

First cost of water-works: $150,000.

Average annual cost of maintenance and repairs: $12,000.

Number of fire-plugs: 1,186.

Design and dimensions of pumps and water-plungers: Five, built by Worthington, New York city; two in 1869–'70, capacity, 5,000,000 gallons each; one in 1874, capacity, 8,000,000 gallons; one in 1876, capacity, 3,000,000 gallons. Plain plungers; on 5,000,000-gallon pumps, 22 inches diameter, 4 feet nominal stroke, 3 feet $\frac{98}{100}$ inch working stroke; on 8,000,000-gallon pump, 28 inches diameter, 50 inches full stroke, 4 feet 1½ inch working stroke; pump-barrels, 22 and 28 inches diameter.

Description of force-mains: 30 inches diameter; head, 165 feet on pumps.

Description of water-valves: Rubber, 9 and 10½ inches diameter; lift, about 1 inch.

Kind of power used: Steam.

Description of boilers: Seven tubular, 18 feet long, 5 feet diameter, and 18 feet long, 6 feet diameter; fuel, Schuylkill hard white-ash coal.

NEWARK—Continued.

Description of engines: Compound; one, high-pressure cylinder, 25 inches diameter; low-pressure cylinder, 43.3 inches diameter; 3.98 feet stroke; one, high-pressure cylinder, 29 inches diameter; low-pressure cylinder, 52 inches diameter; slide-valves; bucket air-pumps; jet-condenser.

Remark: Water much contaminated by factories above pumping works.

NEW YORK.

CANAJOHARIE:

Population: 2,013 inhabitants.

Name of corporation: Canajoharie Water-Works Company (private).

Water obtained from: Springs.

Capacity of reservoirs: Conduit, 8,000 to 10,000 gallons; tank, 800 gallons.

Cost of dam: $10,000.

Water first introduced: In 1852.

Description of main conduit: 90 feet long, 4 inches wide, 4 feet deep; stone wall in masonry, and clay puddling; head, 32 feet (average).

Description of distributing reservoir: Area, 16 by 26 feet, 3 feet deep.

Sizes of distributing mains: 12, 6, 4, 3, and 2 inches.

Available head: 40 to 70 pounds.

Total length of distributing mains: 10,019 feet.

Number of water-takers: 90.

Consumption of water: 75 gallons per head per day (estimated).

First cost of water-works: $10,000.

Average annual cost of maintenance and repairs: About $100.

Number of fire-plugs: 11.

Design and dimensions of pumps and water-plungers: Two, built by Rumsey & Co., Seneca Falls, New York; plain plungers, 4 by 16 inches diameter, 8 inches stroke, 6 to 8 strokes per minute; pump-barrel, 4 by 16 inches.

Time pumps are run: Constantly.

Time spent in repairs: Not over four hours per year.

Description of force-main: 11 miles long, 75 pounds pressure on pumps.

Description of water-valves: Brass.

Kind of power used: Water.

Description of water-wheel: Overshot, wooden, 12 feet diameter, 1 foot wide, with buckets 4 by 12 inches; home design; 6 feet head, 6 to 8 revolutions per minute; 51 gallons per minute; discharge, 6 gallons per minute at reservoir.

Cost of wheel and pumps: Wheel, etc., $200; pumps, $100.

CORNING:

Population: 4,802 inhabitants.

Name of corporation: Corning Water Works (private).

Water obtained from: McCullock and Monkey Run creeks.

Capacity of reservoir: 1,500,000 gallons.

Cost of dam: $4,000.

Water first introduced: In 1870.

Description of main conduit: 8 and 6 inches diameter; cast iron.

Discharging capacity: 500,000 gallons per day; head, 50 feet (average).

Description of distributing reservoir: Area, 300 by 150 feet, and 20 feet deep.

Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.

Available head: 230 feet (average).

Total length of distributing mains: About 5 miles.

First cost of water-works: $25,000.

Number of fire-plugs: 40.

Design and dimensions of pumps and water-plungers: Built by George F. Blake Manufacturing Company and by La France Manufacturing Company, Elmira, New York, in 1877; plain plunger, 24 by 14 inches.

Time pumps are run: About half the time.

Description of force-main: 1½ mile long, 6 inches diameter; 130 pounds pressure on pumps.

CORNING—Continued.

Description of water-valves: Rubber, 7 inches diameter.

Kind of power used: Steam.

Description of boilers: 14 feet long, 3½ feet diameter.

Description of engines: Simple, one 24 by 24 inches, and one 24 by 12 inches, 40 to 125 strokes per minute.

Cost of engines and pumps: $5,000.

ELMIRA:

Population: 20,541 inhabitants.

Name of corporation: Elmira Water-Works Company (private).

Water obtained from: (A) supply, Carr's creek; (B) supply, Chemung river.

Total area of water-shed available: (A) supply, 20 square miles.

Character and dimensions of dam: Across ravine forming storage reservoir, 770 feet long, 36 feet high; built of earth; clay and puddled wall in center; slopes 2 to 1 on both sides; upper side lined; stone rip-rap 12 inches thick; flows 22 acres (about).

Cost of dams: First, $81,928 96; second, $10,718 33.

Water first introduced: In 1860.

Description of main conduits: Two pipes, 10 inches diameter, sheet-iron and cement lined; one Wyckoff patent wood pipe, 2 miles long, 12 inches diameter; head, 88 feet (average).

Description of distributing reservoir: Area, about 300 feet square; elevation, 88 feet; capacity, 6,000,000 gallons; water from distributing reservoir is let in through a fountain discharging-trough; cluster of holes for aerating and purifying.

Sizes of distributing mains: 10 to 2 inches.

Available head: 60 feet (average).

Total length of distributing mains: About 27 miles.

Number of water-takers: 772.

Consumption of water: 1,400,000 gallons (estimated).

First cost of water-works: $342,455 79.

Average annual cost of maintenance and repairs: $9,000.

Filtering apparatus: Gallery; 75 feet long, 75 feet distant from river; bottom 5 feet below low-water; gravel; no cleaning.

Number of fire-plugs: 148.

Design and dimensions of pumps and water-plungers: One rotary, built by La France Manufacturing Company, Elmira, New York; one Knowles pump, Warren, Massachusetts, in 1880; plain plunger, 22 inches diameter, 36 inches stroke, 28 strokes per minute; pump-barrel, 22 inches diameter.

Time pumps are run: Constantly for 6 months.

Description of force-main: 12 inches diameter.

Description of water-valves: Rubber, 3 inches diameter, 2 inches lift.

Kind of power used: Steam.

Description of boilers: Two; 60-horse power, 40 to 60 pounds pressure; fuel, bituminous coal, from McIntyre mines.

Description of engine: Knowles simple condensing; cylinder, 30 inches diameter, 36 inches stroke, 28 strokes per minute, slide-valves operated by piston; Knowles condenser.

Cost of engine and pumps: Knowles, about $5,000.

PORT BYRON:

Population: 1,146 inhabitants.

Style of corporation: Municipal.

Water obtained from: Owasco lake.

Cost of dam: $1,600.

Water first introduced: In 1872.

Description of main conduit: 175 feet long, 4 and 6 inches diameter; iron.

Description of distributing reservoir: Area, 155 by 50 feet, and 12 feet deep.

Sizes of distributing mains: 6 and 4 inches.

Available head: 175 feet (average).

Total length of distributing mains: 3½ miles.

Number of water-takers: 30.

First cost of water-works: $10,000.

Average annual cost of maintenance and repairs: $150.

Number of fire-plugs: 30.

PORT BYRON—Continued.

Design of pump and water-plungers: Built by Rumsey, Seneca Falls, New York.

Description of water-wheel: Turbine, 36 inches diameter, 7 feet head, 150 revolutions per minute.

PENNSYLVANIA.

BELLEFONTE:

Population: 3,026 inhabitants.

Style of corporation: Municipal.

Water obtained from: Spring discharging 14,600 gallons per minute.

Capacity of reservoir: 300,000 gallons.

Cost of dam: $75,000 to $80,000.

Water first introduced: In 1830.

Description of main conduit: 6 inches diameter.

Description of distributing reservoir: Built in shape of section of pyramid, small end down; stone and brick, cemented; no cover; capacity, 300,000 gallons; 1,900 feet from and 196 feet above spring.

Size of distributing mains: 6 inches.

Available head: 10 to 200 feet.

Total length of distributing mains: ¾ mile.

Number of water-takers: 500.

Consumption of water: 80 to 100 gallons per head per day (estimated).

Average annual cost of maintenance and repairs: $2,000.

Number of fire-plugs: 40.

Design and dimensions of pumps and water-plungers: Steam-pump built by Knowles, Warren, Massachusetts; plain plunger, 24 inches diameter, 45 strokes per minute; pump-barrel, 24 inches diameter. Water-pump built by W. P. Duncan & Co., Bellefonte, Pennsylvania; plunger, 32 inches stroke, 18½ strokes per minute; pump-barrel, 6 inches diameter.

Time pumps are run: Water, constantly; steam, 2 to 3 hours per day.

Description of force-main: 1,900 feet long, 82½ pounds pressure on pumps.

Description of water-valves: 3 inches diameter.

Kind of power used: Steam and water.

Description of water-wheel: Horizontal, 35 inches diameter, 6 feet head, 90 revolutions per minute; 100 gallons required to lift 1 gallon to reservoir.

Description of boilers: Tubular, 14 feet long, 4 feet diameter; fuel, Snowshoe coal.

Description of engine: Simple; 45 strokes per minute; ordinary valves.

COLUMBIA:

Population: 8,312 inhabitants.

Name of corporation: Columbia Water Company (private).

Water obtained from: River and springs.

Total area of water-shed available: About 2 square miles.

Capacity of reservoirs: 2,000,000 gallons each.

Character and dimensions of dam: Across valley; 250 feet long at top, 20 feet deep; 500 feet long at bottom, 250 wide.

Cost of dam: $4,281 51; reservoir, $15,778 79.

Water first introduced: In 1823.

Description of main conduit: 10 miles long; diameters, 12, 6, and 4 inches; iron.

Discharging capacity: 1,000,000 gallons; 150 feet head (average) of spring above; reservoir, 50 feet head (average).

Description of distributing reservoirs: Two; area, 100 by 150 feet; 9 feet deep each; plank bottom and sides, caulked and pitched; earth embankment 9 feet above ground level.

Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.

Available head: 50 to 75 feet.

Total length of distributing mains: 10 miles.

Consumption of water: 75 gallons per head per day.

First cost of water-works: $15,500.

Average annual cost of maintenance and repairs: $4,000.

Number of fire-plugs: 50.

COLUMBIA—Continued.

Design and dimensions of pumps and water-plungers: Built by Morris, Tasker & Co., Philadelphia, Pennsylvania, and one by Worthington; two plungers, Worthington, iron, with brass packing, 12 inches diameter, 25 strokes per minute; pump-barrel, 12 inches diameter.

Time pumps are run: 10 to 18 hours per day.

Description of force-main: 4,500 feet long; head, 150 feet on pumps, or 9,000 pounds.

Description of water-valves: Gum, ½ and 3 inches.

Kind of power used: Steam.

Description of boilers: Two; plain cylinder, 65 to 70 pounds pressure, and one flue-boiler.

Description of engine: Non-condensing simple; cylinders, 18 inches diameter, 50 strokes per minute; globe-valves.

Cost of engine and pumps: About $10,000.

Duty of engine: 3,400,000 foot-pounds per 15 hours daily.

LEWISTOWN:

Population: 3,222 inhabitants.

Name of corporation: Lewistown Water Company (private).

Water obtained from: Creek and springs.

Total area of water-shed available: About 4 square miles.

Area and capacity of reservoir: 2,500 sq. feet; 17,500 cu. feet.

Cost of dam: $24,000.

Water first introduced: In 1839.

Description of main conduit: 3 miles long, 6 inches diameter; iron; head, 80 feet (average).

Description of distributing reservoir: Ordinary; 50 feet square and 7 feet deep.

Sizes of distributing mains: 6 and 4 inches.

Available head: About 50 feet (average).

Total length of distributing mains: 5 miles.

Number of water-takers: About 500.

First cost of water-works: $20,000.

Average annual cost of maintenance and repairs: $1,500.

Number of fire-plugs: 14.

Design and dimensions of pump and water-plungers: Built by Worthington, New York, in 1870; two plain plungers, 6 inches diameter, 8 inches stroke, 60 strokes per minute.

Time spent in repairs: 75 hours per year.

Description of force-main: 1½ mile long; head, 15 feet on pump.

Description of water-valves: Rubber, 2 inches, ½ inch lift.

Kind of power used: Steam.

Description of boilers: Tubular, 8 feet long, 3 feet diameter; fuel, bituminous coal.

Description of engine: 60 strokes per minute; globe-valves; Worthington duplex pump condenser, etc.

Cost of engine and pump: $3,000.

Remarks: The disadvantage of pumping to mains is that when water is being shut off at the hydrants it is forced back on pumps, causing wear.—When pumping from creek after rain water is muddy; water is a little hard on account of limestone.

VIRGINIA.

STAUNTON:

Population: 6,664 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Springs.

Capacity of reservoir: 2,500,000 gallons.

Cost of dam: $82,000.

Water first introduced: In 1876.

Description of main conduit: 5,692 feet long, 12 inches diameter; cast iron.

Discharging capacity: Head, 180 feet (average); 1,125,000 gallons per day.

Description of distributing reservoir: Circular, 225 feet diameter at top, 16 feet deep; has a receiving well with a wire strainer through which the water passes.

Sizes of distributing mains: 12, 6, and 3 inches.

Available head: 180 feet (average).

Total length of distributing mains: About 8 miles.

STAUNTON—Continued.

Number of water-takers: 1,500.
Consumption of water: 67 gallons per head per day (estimated).
Average annual cost of maintenance and repairs: $2,600.
Number of fire-plugs: 28.
Design and dimensions of pump and water-plungers: Built by H. R. Worthington, New York; two plain plungers, 13 inches diameter, 24 inches stroke, 15 strokes per minute; pump barrel, 23 by 56 inches.
Time pump is run: 10.53 hours of 300 days per year.
Time spent in repairs: 7 to 8 days per year.
Description of force-main: 1,500 feet long, 12 inches diameter, 77 pounds pressure on pump.
Description of water-valves: Gum.
Kind of power used: Steam.
Description of boilers: 16 feet long, 5 feet diameter; fuel, New River soft coal.
Description of engine: Condensing duplex compound; high-pressure cylinder, 17¼ inches diameter; low-pressure cylinder, 35 inches diameter; 24 inches stroke, 15 strokes per minute; slide-valves; ordinary lifting air-pumps, 6 inches; condenser, 24 by 48 inches.
Cost of engine and pumps: $13,500.
Duty of engine: 42,269,392 foot-pounds daily.

755

WASHINGTON TERRITORY.

OLYMPIA:

Population: 1,232 inhabitants.
Name of corporation: Olympia Water Company (private).
Water obtained from: Springs and river.
Cost of dam: $500.
Water first introduced: In 1865.
Description of main conduit: Wyckoff wood pipe, 4 inches diameter; head, 150 feet (average).
Description of distributing reservoir: Tank, 50 feet square and 12 feet deep.
Sizes of distributing mains: 6 and 4 inches.
Available head: 80 feet (average).
Total length of distributing mains: 9 miles.
Number of water-takers: 100.
First cost of water-works: $20,000.
Number of fire-plugs: 2.
Design and dimensions of pump and water-plungers: Hooker pump, 90 strokes per minute; pump-barrel, 6 inches diameter.
Time pump is run: Constantly.
Description of water-valves: Composition rubber.
Kind of power used: Water.
Description of water-wheel: Leffel turbine, 23 inches diameter, 31 feet head, 320 revolutions per minute.

WATER-WORKS EMPLOYING THE GRAVITY SYSTEM AND PUMPING TO STAND-PIPE.

MINNESOTA.

STILLWATER:

Population: 9,055 inhabitants.
Name of corporation: Stillwater Water Company (private).
Water obtained from: Lake McKussick.
Total area of water-shed available: 40 square miles.
Area of reservoir: Lake, 30 acres.
Character and dimensions of dams: Filtering, 100 by 60 feet, and 10 feet deep; reservoir, 100 by 150 feet, and 12 feet deep.
Cost of dams: $4,000.
Water first introduced: December, 1880.
Description of main conduit: 200 feet long, 20 inches diameter; tile.
Discharging capacity: 5,000,000 gallons per day; head, 8 to 10 feet.
Description of stand-pipes: Tanks, on two hills; capacity, 100,000 gallons each; 1 mile from pumping station.
Sizes of distributing mains: 16, 12, 10, 8, 6, and 4 inches.
Available head: 50 to 200 feet.
Total length of distributing mains: 7½ miles.
Number of water-takers: 61.
Consumption of water: 25 gallons per head per day (estimated).
First cost of water-works: $150,000.
Filtering apparatus: Gallery, 60 by 100 feet, and 10 feet deep; sand and gravel, underlaid by 4 by 4 inch and 2½ by 4 inch timbers; cleaned once a year.
Number of fire-plugs: 85.
Design and dimensions of pump and water-plungers: Harrison, built by Blake Manufacturing Company, Boston, Massachusetts; piston, 1 to 150 strokes per minute; pump-barrels, 10 by 24 inches.
Time pump is run: 2 hours per day.
Description of force-main: 3 miles long, 16, 12, and 8 inches diameter, 60 pounds pressure on pump.
Description of water-valves: Har rubber, 4 inches diameter, ⅝ inch lift.
Kind of power used: Steam.
Description of boilers: Two; 16 feet long, 48 inches diameter.
Description of engine: High-pressure, 24 inches stroke, 1 to 150 strokes per minute; slide-valves operated with piston-valves.
Cost of engine and pump: $4,500.

PENNSYLVANIA.

SOUTH BETHLEHEM:

Population: 4,925 inhabitants.
Name of corporation: South Bethlehem Gas and Water Company (private).
Water obtained from: Lehigh river.
Water first introduced: In 1875.
Sizes of distributing mains: 8, 6, 4, and 3 inches.
Available head: 60 pounds pressure (average).
Total length of distributing mains: 2,305 feet.
Number of water-takers: 140.

SOUTH BETHLEHEM—Continued.

First cost of water-works: $29,184 22.
Average annual cost of maintenance and repairs: $395 83.
Number of fire-plugs: 36.
Design and dimensions of pumps and water-plungers: John Fritz, built by Bethlehem Iron Company; pump-barrels, 18 by 36 inches.
Time pumps are run: One pump constantly.
Description of force-main: 60 to 90 pounds pressure on pumps.
Kind of power used: Steam.
Remarks: The disadvantage of pumping to mains is that muddy water is pumped into mains after rains.

TENNESSEE.

CLARKSVILLE:

Population: 3,880 inhabitants.
Name of corporation: Clarksville Water Company (private).
Water obtained from: Cumberland river.
Water first introduced: June, 1879.
Description of main conduit: 10,200 feet long, 8 inches diameter; cast iron.
Discharging capacity: 500,000 to 1,000,000 gallons per day; head, 150 to 250 feet.
Description of stand-pipe: Riveted plate iron; 15 feet interior diameter; 102 feet high; on stone foundation.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 150 to 200 feet.
Total length of distributing mains: $5\frac{1200}{2280}$ miles.
Number of water-takers: 102.
Consumption of water: 31 gallons per head per day (estimated).
First cost of water-works: $50,000.
Average annual cost of maintenance and repairs: $2,500.
Number of fire-plugs: 40.
Design and dimensions of pumps and water-plungers: Two; built by Blake Manufacturing Company, Boston, Massachusetts; bucket-plungers; steam, 20 inches; water, 12 by 24 inches; 45 strokes per minute; pump-barrel, 12 inches diameter.
Time pumps are run: Five hours per day, four days per week.
Description of force-main: 10,200 feet long, 8 inches diameter; head, 281 feet on pumps.
Description of water-valves: Composition of gum and metal; 4¾ inches diameter, 1 inch lift.
Kind of power used: Steam.
Description of boilers: 22 feet long, 44 inches diameter; 5 riveted flues, 8 inches diameter; fuel, bituminous coal.
Description of engine: Simple; high-pressure; cylinder, 20 inches diameter, 24 inches stroke, 45 strokes per minute; Blake patent valves.
Cost of engine and pumps: $3,000.
Remarks: The disadvantage of pumping is the uneven strain on pipe-joints.—Water slightly impregnated with lime.

WATER-WORKS EMPLOYING THE GRAVITY SYSTEM AND PUMPING DIRECT INTO DISTRIBUTING MAINS.

NEBRASKA.

OMAHA:

Population: 30,518 inhabitants.

Name of corporation: City Water-Works (private).

Water obtained from: Missouri river.

Capacity of reservoir: 9,000,000 gallons.

Description of main conduit: 16 and 24 inches diameter; cast iron.

Discharging capacity: 5,000,000 gallons per day of 12 hours; head, 235 feet (average).

Description of distributing reservoir: Two chambers, 204 by 162 feet; 24 feet deep, each; embankment, 12 feet wide at top; slopes, 1½ to 1; elevation of top of embankment, 307 feet above low water of river; interior puddled and lined with broken stone at bottom, and brick on slopes.

Sizes of distributing mains: 24 to 8 inches.

Available head: 150 feet (average).

Total length of distributing mains: 31 miles.

Number of water-takers: 395.

Consumption of water: 50 gallons per head per day (estimated).

First cost of water-works: $500,000.

Filtering system: Water pumped from river into three settling basins, capacity 3,000,000 gallons, from whence it is drawn into clear water basin, and from thence into distributing reservoir.

Number of fire-plugs: 250.

Design and dimensions of pumps and water-plungers: Knowles plain compound, 24 inches diameter, 42 inches stroke; high pressure, 19 inches diameter, 36 inches stroke; pump barrel, 24 inches diameter.

Time pumps are run: 12 hours per day.

Description of force-main: 2½ miles long, 16 inches diameter; head, 283 feet; pumps.

Description of water-valves: Rubber, with leather face, 3¼ inches in size, ½ to ⅝ inch lift.

Kind of power used: Steam.

Description of boilers: Return-flue; fuel, bituminous coal.

Description of engines: One compound condensing; high-pressure cylinder, 33 inches diameter; low-pressure cylinder, 61 inches diameter; 42 inches stroke. One extra engine; cylinder, 38 inches diameter; 36 inches stroke; rotary piston; slide-valves, operated by rocker-valve attached to piston; air-cylinder, 16 inches diameter; one 30-inch jet-condenser.

Cost of engines and pumps: $10,000.

Duty of engines: 80,000,000 foot-pounds guaranteed.

NEW YORK.

YONKERS:

Population: 18,892 inhabitants.

Name of corporation: Yonkers Water-Works (municipal).

Water obtained from: Sprain and Grassy Sprain brooks.

Total area of water-shed available: 8 square miles possible; 6 square miles at present.

YONKERS—Continued.

Area and capacity of reservoir: 104 acres; 405,000,000 gallons.

Character and dimensions of dam: Earth, with puddle core; width on top, 20 feet; slopes, 2 to 1; faced on water side with rubble 18 inches thick; greatest depth of water, 26 feet; foundation mainly on sand and gravel, also on rock and hard pan; heavy base of concrete for puddle-wall, secured by sheet-piling and core-walls where necessary.

Cost of dam: $73,000.

Water first introduced: September, 1876.

Description of main conduit: 3,200 feet long, 24 inches diameter; cast iron.

Discharging capacity: About 4,000,000 gallons per day; head, 26 feet (maximum).

Description of distributing reservoir: Very small affair; holds about 2 days' supply.

Sizes of distributing mains: 18, 12, 8, 6, and 4 inches.

Available head: 0 to 297 feet.

Total length of distributing mains: 6,500 feet of 18 inches, 25,951 feet of 12 inches, 15,863 feet of 8 inches, 47,042 feet of 6 inches, 14,619 feet of 4 inches.

Number of water-takers: 995.

Consumption of water: 80 gallons per head per day (estimated).

First cost of water-works: To December 1, 1880, $669,299 66.

Average annual cost of maintenance and repairs: $3,500.

Number of fire-plugs: 248.

Design and dimensions of pumps and water-plungers: One built by W. Wright, Newburg, New York, in 1876; one bucket-plunger, 15½ inches diameter, 36 inches stroke, 17 strokes per minute; pump-barrel, 22 inches diameter. One H. R. Worthington, New York, in 1881; two plain plungers, 18½ inches diameter, 36 inches stroke, 50 strokes per minute.

Time pumps are run: 3,274 hours in 1880.

Time spent in repairs: Nominal.

Description of force-main: 8,500 feet long, 18 inches diameter; head on Wright pump, 198 feet; head on Worthington pump, 210 feet.

Description of water-valves: Wright, double-beat; Worthington, disk.

Kind of power used: Steam.

Description of boilers: Drop return tubular, 18 feet long, 5½ feet diameter; fuel, anthracite coal.

Description of engines: Condensing compound; Wright, 22 and 36 inches diameter, 5 feet stroke, 17 strokes per minute; slide-valves operated by eccentric on shaft. Worthington 31 and 36⅜ inches diameter, 3 feet stroke, 50 strokes per minute; balanced slide-valve; single-acting, brass-lined air-pumps.

Cost of engines and pumps: Wright, $17,500; Worthington, $21,000.

Duty of engines: Wright, 61,000,000 foot-pounds daily in 1880; 80,000,000 foot-pounds guaranteed. Worthington, 70,000,000 foot-pounds guaranteed.

PENNSYLVANIA.

SHAMOKIN:

Population: 8,184 inhabitants.
Name of corporation: Shamokin Water Company (private).
Water obtained from: Trout run.
Total area of water-shed available: 2,000 acres.
Capacity of reservoir: 250,000 cubic feet.
Character and dimensions of dams: Two; one ½ mile above the other.
Cost of dams: $4,000.
Water first introduced: In 1874.
Description of main conduit: 2¼ miles long, 12 inches diameter; wood, iron bound; and 3¼ miles long, 12 inches diameter, iron.
Discharging capacity: Lower dam, 49 feet, upper dam, 139 feet; 800 gallons per minute.
Description of stand-pipe: 250 feet, up the mountain.
Sizes of distributing mains: 10 to 4 inches.
Available head: 139 feet (average).
Total length of distributing mains: About 9 miles.
Number of water-takers: About 1,000.
Consumption of water: 100 gallons per day per family (estimated).
First cost of water-works: $110,000.
Average annual cost of maintenance and repairs: $2,000 to $3,000.
Number of fire-plugs: 20.
Design and dimensions of pumps and water-plungers: Built by the Niagara Pump Works, Brooklyn, New York; double plungers, 8½ inches diameter, 18 inches stroke, 20 to 40 strokes per minute; pump-barrel, 8½ inches diameter.
Time pumps are run: About 3 months per year.
Time spent in repairs: 600 hours per year.
Description of water-valves: Brass.
Kind of power used: Steam.
Description of boilers: Steam, from Cameron colliery; fuel, anthracite coal.
Cost of engine and pump: $750.

WILKESBARRE:

Population: 23,339 inhabitants.
Name of corporation: Wilkesbarre Water Company (incorporated stock company).
Water obtained from: Mountain stream.
Total area of water-shed available: About 12,000 acres.
Capacity of reservoir: 7,000,000 gallons.
Character and dimensions of dam: Stone, 20 feet high.
Cost of dam: $15,000.
Water first introduced: In 1860.
Description of main conduit: 2½ miles, 16 inches diameter, cast iron; and 2½ miles, 10 inches diameter, wrought iron and cement; head, 150 feet (average).
Sizes of distributing mains: 10, 8, 6, 4, and 3 inches.
Available head: 150 feet (average); water-supply deficient.

WILKESBARRE—Continued.

Total length of distributing mains: About 35 miles.
Number of water-takers: About 2,800.
First cost of water-works: $180,000.
Average annual cost of maintenance and repairs: $2,000.
Number of fire-plugs: 94.
Design and dimensions of pump and water-plungers: Built by G. F. Blake Manufacturing Company, in 1877; bucket-plungers, 50 to 60 strokes per minute; pump-barrels, 10 inches diameter; head, 130 feet on pumps.
Time pump is run: 2 days per year (average).
Description of water-valves: Leather.
Kind of power used: Steam.
Description of boilers: 55 pounds pressure; fuel, No. 3 anthracite coal.
Description of engine: 50 to 60 strokes per minute.
Cost of engine and pump: $2,100.
Remarks: The advantages of pumping to mains are that it saves trouble and that it is easy to get the water quickly.

VERMONT.

SAINT JOHNSBURY:

Population: 5,800 inhabitants.
Name of corporation: Saint Johnsbury Aqueduct Company and Village of Saint Johnsbury Water-Works (private).
Water obtained from: Saint Johnsbury Aqueduct, springs; Village, from river.
Total area of water-shed available: 1,000 acres.
Water first introduced: Saint Johnsbury Aqueduct, in 1850; Village, in 1876–'77.
Description of main conduit: Saint Johnsbury Aqueduct Company, 4 miles long, 6 inches diameter; iron, cement-lined; head, 170 feet (average).
Sizes of distributing mains: Saint Johnsbury Aqueduct Company, 4 and 3 inches; Village, 8, 6, and 4 inches.
Available head: 170 feet (average).
Consumption of water: 2,000 gallons per day (estimated).
First cost of water-works: Saint Johnsbury Aqueduct Company, $50,000; Village, $80,000.
Filtering apparatus: Size, 12 by 15 feet; filled with sand; cleaned once in two weeks.
Number of fire-plugs: 50.
Design and dimensions of pumps and water-plungers: Village pumps, built by J. P. Flanders, Vergennes, Vermont, in 1874; buckets, small pump, 18 inches stroke; large pump, 8 inches stroke; 20 strokes per minute; pump-barrels, 12 by 15 inches; 80 to 100 pounds pressure on pumps.
Time pumps are run: Constantly.
Description of water-valves: Plain metallic; small pump, 12 inches and ⅜ inch lift; large pump, 15 inches and ⅜ inch lift.
Kind of power used: Water.
Description of water-wheels: One for each pump; Buzzell make; 30 and 50 inches diameters; 12 feet head.

WATER-WORKS EMPLOYING SYSTEM OF PUMPING TO DISTRIBUTING RESERVOIR AND STAND-PIPE.

ALABAMA.

MOBILE:

Population: 29,132 inhabitants.
Name of corporation: Mobile Water Company (private).
Water obtained from: Springs and creek.
Water first introduced: In 1824.
Description of distributing reservoir and stand-pipe: Rectangular embankment; puddle-faced and riprap of brick; inner slope, 2 to 1; outer slope, 1½ to 1; stand-pipe, cast iron, 9 inches diameter, 85 feet high, with an exterior of 3 inches; pipe, 12 feet high; the whole supported in a skeleton framework.
Sizes of distributing mains: 14, 10, 8, 6, and 4 inches.
Water supply: Deficient.
Number of water-takers: About 1,000.
Consumption of water: About 250,000 gallons per day.
First cost of water-works: $200,000.
Average annual cost of maintenance and repairs: $12,000.
Number of fire-plugs: 172.
Design and dimensions of pumps and water-plungers: Two; built by Paulding, Kemple & Co., West Point; plain double-acting piston-plunger; 10 inches diameter; 48 inches stroke; 17 strokes per minute.
Time pumps are run: Constantly.
Description of force-main: 16,000 feet long; 8 inches diameter; head, 20 feet on pumps.
Description of water-valves: Hinge, 6 by 12 inches; free lift.
Kind of power used: Water.
Description of water-wheels: Two breast-wheels; 16 inches diameter; 7 feet wide; 10 inches deep; 5½ feet head; 8½ revolutions per minute.
Remarks: Two Blake pumps are being introduced.

MASSACHUSETTS.

BROOKLINE:

Population: 8,057 inhabitants.
Name of corporation: Brookline Water-Works (municipal).
Water obtained from: Springs.
Cost of dam: $78,312.
Water first introduced: May, 1875.
Description of distributing reservoir and stand-pipe: On a hill, 240 feet above tide-water; 360 by 130 feet; 20 feet deep; lined with stone rubble masonry; capacity, 6,000,000 gallons; partly built by embankment. Stand-pipe, 25 feet high; 6 feet inside diameter; built of masonry.
Sizes of distributing mains: 16 to 2 inches.
Available head: From 0 to 220 feet.
Total length of distributing mains: About 25 miles.
Number of water-takers: 896.
Consumption of water: 69 gallons per head per day (exact).
First cost of water-works: $475,000.

BROOKLINE—Continued.

Average annual cost of maintenance and repairs: $6,800.
Filtering apparatus: Size, 200 by 4 feet; filtering required only occasionally; gravel; cleaned once a month, while in use.
Number of fire-plugs: 158.
Design and dimensions of pumps and water-plungers: Built by Worthington, New York, in 1874 and 1880; two plain plungers; one 16 inches diameter and one 14¾ inches diameter; 25¾ inches stroke; 24 strokes per minute; pump-barrels, about 2 feet.
Time pumps are run: About 3,400 hours per year.
Time spent in repairs: 250 hours per year.
Description of force-main: 2¼ miles long; 16 and 14 inches diameter.
Description of water-valves: Vulcanized rubber; 7 by 1 inch; ¾ inch lift.
Kind of power used: Steam.
Description of boilers: Two horizontal tubular; 16 feet long; one 5 feet 3 inches diameter; one 5 feet 6 inches diameter; evaporation, 8½ pounds of water to 1 pound of coal; 55 pounds pressure; fuel, anthracite coal.
Description of engine: Compound condenser, intermediate receiver; high-pressure cylinder, 21½ inches diameter; low-pressure cylinder, 43½ inches diameter; 25¾ inches stroke; 48 strokes per minute; slide-balanced valves, worked by opposite bell-crank; two single-acting air-pumps, volume, 5,304 cubic inches; condenser volume, 25,000 cubic inches.
Cost of engine and pumps: $16,000.
Duty of engine: 53,000,000 foot-pounds, daily; 50,000,000 foot-pounds guaranteed.

CAMBRIDGE:

Population: 52,669 inhabitants.
Name of corporation: City Water-Works (municipal).
Water obtained from: Fresh pond.
Total area of water-shed available: 1,200 acres.
Water first introduced: In 1856.
Description of distributing reservoir and stand-pipe: Stand-pipe near reservoir; pumping mains enter it at bottom and connect with distributing mains, these connect with reservoir; an outlet from reservoir connects direct with stand-pipe.
Sizes of distributing mains: 24, 20, 16, 12, 10, 8, 6, 4, and 3 inches.
Available head: 60 feet (average); water-supply deficient.
Total length of distributing mains: 80 miles.
Number of water-takers: 10,400.
Consumption of water: 46 gallons per head per day.
First cost of water-works: $291,480.
Average annual cost of maintenance and repairs: $25,000.
Filtering apparatus: Gallery excavated near edge of little pond; size, 45 by 50 feet; gravel; no cleaning.

CAMBRIDGE—Continued.

Number of fire-plugs: 375.

Design and dimensions of pumps and water-plungers: Two built by Worthington, New York, in 1868 and 1872; two plain plungers to each; 22 inches diameter; 48 inches stroke; 26 strokes per minute; pump-barrels 22 by 48 inches.

Time pumps are run: 11 hours per day.

Description of force-main: 2,400 feet long; one 30 inches diameter and one 24 inches diameter; 48 pounds pressure on pumps.

Description of water-valves: Rubber; 9 inches diameter; ⅞ inch lift.

Kind of power used: Steam.

Description of boilers: Four horizontal tubular; two 13 feet long, 63 inches diameter; two 13 feet 6 inches long, 66 inches diameter; 45 pounds pressure; fuel, Cumberland coal.

Description of engine: Compound condensing; high-pressure cylinder, 14 inches diameter; low-pressure cylinder, 24 inches diameter; 48 inches stroke; 52 strokes per minute (average); slide-valves with piston counter-balance operated from opposite cross-head; single-acting air-pump; jet-condenser.

Cost of engine and pumps: $68,000.

Duty of engine: 50,000,000 foot-pounds daily.

OHIO.

WEST CLEVELAND:

Population: 1,800 inhabitants.

Supplied by Cleveland water-works (see pages 112 and 113).

ZANESVILLE:

Population: 18,113 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Muskingum river.

Water first introduced: In 1842.

Discharging capacity of conduit: 5,000,000 gallons in 24 hours; head, 180 feet (average).

Description of distributing reservoirs and stand-pipe: Two reservoirs for low service; capacity, 5,000,000 gallons; stand-pipe for high service; head, 80 feet above reservoir.

Sizes of distributing mains: 16 to 3 inches.

Available head: 180 feet (average).

Total length of distributing mains: 34 miles.

Number of water-takers: 3,000.

Consumption of water: 96 gallons per head per day (estimated).

First cost of water-works: $500,000.

Average annual cost of maintenance and repairs: $12,000.

Number of fire-plugs: 163.

Design and dimensions of pump and water-plunger: Worthington, New York, duplex; plain plunger, 18 inches diameter; 36 inches stroke; 60 strokes per minute; pump-barrel, 17½ by 36 inches.

Time pump is run: 15 hours per day.

Description of force-main: 2,800 feet long; 20 inches diameter; 70 pounds pressure on pump.

Description of water-valves: Gum; 7 inches diameter; 1 inch lift.

Kind of power used: Steam.

Description of boilers: Four tubular; 14 feet long, 54 inches diameter; 60 tubes, 3 inches diameter each; 65 pounds pressure; fuel used, slack.

Description of engine: Non-condensing; cylinder, 30 inches diameter; 36 inches stroke; 60 strokes per minute; globe throttle-valves.

Cost of engine and pump: $17,000.

PENNSYLVANIA.

ALLENTOWN:

Population: 18,063 inhabitants.

Style of corporation: Municipal.

Water obtained from: Springs.

Character and dimensions of dam: Wooden structure; 140 feet wide and 6 feet high.

ALLENTOWN—Continued.

Water first introduced: In 1820.

Description of main conduit: 2,230 feet long; 12 inches diameter; cast iron.

Discharging capacity: 1,300,000 gallons in 24 hours; head, 6 feet (average).

Description of distributing reservoir and stand-pipe: The former, 48 by 28 feet and 13 feet deep; bottom 142 feet above level of pump; capacity, 276,019 gallons. The latter, 57 feet high, 6 feet diameter; base 128 feet above pump; capacity, 134,222 gallons.

Sizes of distributing mains: 16 to 2 inches.

Available head: 8 to 136 feet; water-supply deficient.

Total length of distributing mains: 22 miles.

Number of water-takers: 2,350.

Consumption of water: About 800,000 gallons per day (estimated).

First cost of water-works: $97,000.

Number of fire-plugs: 92.

Design and dimensions of pump and water-plungers: Built by W. F. Moser & Co., Allentown, Pennsylvania, in 1872; two plain plungers; 5 feet 2 inches; 12½ strokes per minute; pump-barrel, 10 inches diameter.

Time pump is run: Constantly.

Description of force-main: 1,000 feet long; 10 inches diameter; 142.5 pounds pressure on pump.

Description of water-valves: Brass; 10 by 14 inches; 1 inch lift.

Kind of power used: Water.

Description of water-wheel: Wolfe's patent turbine; 6 feet diameter; 6 feet head; 30 revolutions per minute.

WISCONSIN.

MILWAUKEE:

Population: 115,587 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Lake Michigan.

Water first introduced: In November, 1873.

Description of main conduit: From lake-crib to pump well, 2,100 feet long; 36 inches diameter; cast iron; the head or difference of level between lake and pump-well depends on speed of pumps, being 3 feet 2 inches when engines are pumping at the rate of 16,000,000 gallons per 24 hours.

Description of distributing reservoir and stand-pipe: Reservoir capacity, 21,000,000 gallons; embankment, 16 feet wide on top; inner slope, 1¾ to 1; outer slope, 1½ to 1; inner slope and bottom covered with, first, clay puddle 2 feet thick; second, 9 inches broken stone; third, paving 15 inches thick, laid in cement and mortar; water enters on east side; effluent-chamber, stop-valves, waste- and overflow-pipes on west side; influent- and effluent pipes connected by main on bottom of reservoir for direct supply in case of necessity. Stand-pipe, wrought iron; 4 feet diameter; 130 feet high; inclosed in stone tower.

Sizes of distributing mains: 30, 24, 20, 16, 12, 8, and 6 inches.

Available head: 90 to 140 feet, according to location.

Total length of distributing mains: 90 miles.

Number of water-takers: 7,524.

Consumption of water: 12,269,000 gallons per day; about 100 gallons per head (average).

First cost of water-works: $1,967,500.

Average annual cost of maintenance and repairs: $60,000.

Number of fire-plugs: 716.

Design and dimension of pumps and water-plungers: R. W. Hamilton, built by E. P. Allis & Co., Milwaukee, Wisconsin, in 1873; two bucket-plungers; 28⅛ inches diameter; 7 feet stroke; 26 strokes per minute; pump-barrel, 3 feet 4 inches diameter.

Time pumps are run: About 18 hours per day.

MILWAUKEE—Continued.

Description of force main: 525 feet long; 36 inches diameter; head, about 170 feet on pumps.

Description of water-valves: Bucket, double-seated; outside diameter lower seat, 34 inches; inside diameter, 20 inches; $1\frac{7}{8}$ inch lift.

Kind of power used: Steam.

Description of boilers: Drop return-flue; 24 feet long; 7 feet diameter; 60 pounds pressure; evaporation, 9.15 pounds of water to 1 pound of coal; fuel, anthracite coal.

761

MILWAUKEE—Continued.

Description of engines: Condensing compound; high-pressure cylinder, 36 inches diameter, 62.14 inches stroke; low-pressure cylinder, 58 inches diameter, 96 inches stroke; 26 strokes per minute; ordinary steam-valve, operated by cam cut-off; single-acting air-pump, 30 inches diameter, 62 inches stroke; common condenser, 36 inches diameter, 84 inches high.

Cost of engines and pumps; $170,000.

Duty of engines: 75,000,000 to 80,000,000 foot-pounds, daily; 60,000,000 foot-pounds guaranteed.

WATER-WORKS EMPLOYING SYSTEM OF PUMPING TO DISTRIBUTING RESERVOIR AND MAINS.

ALABAMA.

BIRMINGHAM:

Population: 3,086 inhabitants.
Name of corporation: Elyton Land Company (private).
Water obtained from: Creek.
Total area of water-shed available: 40 square miles.
Capacity of reservoir: 1,000,000 gallons.
Cost of dam: $7,500.
Water first introduced: In May, 1873.
Description of main conduit: Part of stone, 30 by 30 inches square; part cast iron, 4,600 feet long; 12 inches diameter.
Discharging capacity: 3,000,000 gallons per day.
Description of distributing reservoir: Dimensions—58 by 95 feet, bottom; 100 by 150 feet, top; 12½ feet deep; embankment of earth, lined inside with one course of brick, and one edge laid in cement.
Sizes of distributing mains: 8, 6, 4, 3, and 2 inches.
Available head: 130 feet (average).
Total length of distributing mains: About 8 miles.
Number of water-takers: 450.
Consumption of water: 100 gallons per head per day (estimated).
First cost of water-works: About $90,000.
Average annual cost of maintenance and repairs: $300 to $500.
Number of fire-plugs: 15.
Design and dimensions of pumps and water-plungers: One Worthington; pump-barrel, 10 by 10 inches. One Blake; pump-barrel, 14 by 24 inches. One Williamson; pump-barrel, 10 by 24 inches; 100 strokes per minute.
Time pumps are run: 10 hours per day for 2 pumps.
Description of force-main: 4,600 feet long; 12 inches diameter; head, 175 feet on pumps.
Description of water-valves: Rubber; 3 and 3½ inches diameter; ¾ inch lift.
Kind of power used: Steam.
Description of boilers: Two—14 feet long, 50 inches diameter; 60 tubes 3 inches diameter in each. One flue—28 feet long, 42 inches diameter; 16 flues, 2 inches each.
Description of engines: Worthington, duplex, high-pressure; 1[illegible]½ by 10 inches; plain slide-valve. Williamson, 18½ by 24 inches; steam shifting-valves. Blake compound condensing duplex; 14 by 24 inches; plain slide-valve. Air-pump—steam-cylinder, 10 inches; air-cylinder, 14 inches; 18 inches stroke.
Cost of engines and pumps: Worthington, $1,500; Williamson, $1,050; Blake, $5,500.

FLORIDA.

JACKSONVILLE:

Population: 7,650 inhabitants.
Name of corporation: Jacksonville Water-Works (municipal).
Water obtained from: Well and stream.
Water first introduced: July, 1880.

JACKSONVILLE—Continued.

Description of stand-pipe: 10 inches; cast iron; 100 feet high; in case of fire this is shut off and direct pumping is practiced.
Sizes of distributing mains: 14 to 6 inches.
Available head: 100 feet (average).
Total length of distributing mains: 8 miles.
Number of water-takers: 150.
Consumption of water: 80,000 gallons per day (exact).
First cost of water-works: $95,000.
Number of fire-plugs: 87.
Design and dimensions of pump and water-plungers: Built by Worthington, New York, in 1880; plain plungers; 6½ strokes per minute; pump-barrel, 18 by 36 inches and 16 by 24 inches.
Time pump is run: Constantly.
Description of force-main: 1,420 feet long; 14 inches diameter; 45 pounds pressure on pump.
Description of water-valves: Rubber; 6½ inches diameter; 1 inch lift.
Kind of power used: Steam.
Description of boilers: Return tubular; 16 feet long; 5 feet diameter; 64 tubes, 4 inches diameter each; fuel, wood.
Description of engines: One compound condensing, 14 by 18 inches; 24 by 18 inches; one high-pressure, 18½ by 10 inches; 6½ strokes per minute; slide-valves operated by opposite engine; four single-acting air-pumps, 12 inches diameter; 10 inches stroke; jet-condenser, 18 by 36 inches.
Cost of engines and pumps: $20,000.

ILLINOIS.

ALTON:

Population: 8,975 inhabitants.
Name of corporation: Alton Water-Works (private).
Water obtained from: Mississippi river.
Water first introduced: January, 1876.
Description of main conduit: 5 feet high by 2 feet wide; stone laid in cement; head, 3 to 30 feet.
Description of distributing reservoirs: Two tanks, elevated 50 feet above highest point of city; one 40 feet diameter, 24 feet high; the other 30 feet diameter, 16 feet high, set on trestle, making top of tanks 250 feet above pumps.
Sizes of distributing mains: 16, 10, 8, and 6 inches.
Available head: 150 to 250 feet.
Total length of distributing mains: 12 miles.
Number of water-takers; 106.
Consumption of water: 200,000 gallons per day (estimated)
First cost of water-works: $90,000.
Average annual cost of maintenance and repairs: $3,600.
Filtering apparatus: Box filled with sponges; cleaned once a month.
Number of fire-plugs: 87.
Design and dimensions of pumps and water-plungers: Built at Indianapolis; 26 to 30 strokes per minute; pump-barrel, 12 by 30 inches. Worthington, New York, pump being put in now.

ALTON—Continued.

Time pump is run: 3½ hours per day.

Description of force-main: 1¼ mile long; head, 250 feet on pump.

Description of water-valves: Rubber.

Kind of power used: Steam.

Description of boilers: Four, 20 feet long; 48 inches diameter; 60 to 70 pounds pressure; fuel, bituminous coal.

Description of engines: Dean; 24 inches diameter; 24 inches stroke; Worthington; 18½ by 14 by 10 inches; double.

Cost of engines and pump: Dean, $5,000.

JACKSONVILLE:

Population: 10,927.

Name of corporation: Jacksonville Water-Works (municipal).

Water obtained from: Reservoir and creek.

Total area of water-shed available: Reservoir, 4 square miles; creek, 20 square miles.

Capacity of receiving reservoir: 6,000,000 gallons.

Character and dimensions of dam: 18 feet high across valley.

Cost of dam: $25,000.

Water first introduced: February, 1874.

Description of distributing reservoir: Circular; 135 feet diameter on bottom; 185 feet diameter on top; 15 feet deep; capacity, 2,500,000 gallons; situated on an eminence.

Sizes of distributing mains: 10 to 4 inches.

Available head: 86 feet (average); water-supply deficient.

Total length of distributing mains: 9 miles.

Number of water-takers: 350.

Consumption of water: 212,000 gallons per day (exact).

First cost of water-works: $150,000.

Average annual cost of maintenance and repairs: $3,500 to $4,000.

Number of fire-plugs: 75.

Design and dimensions of pump and water-plungers: Built by Worthington, New York, in 1878; two plain plungers, 15 inches diameter; 16 inches stroke; 16 to 18 strokes per minute; pump-barrel about 31 inches diameter.

Time pump is run: About 18 hours per day.

Time spent in repairs: None.

Description of force-main: 2½ miles long; 10 inches diameter; head, 120 to 134.85 feet on pump.

Description of water-valves: Soft rubber, 1 inch thick; 8 inches diameter; ½ inch lift.

Kind of power used: Steam.

Description of boilers: Two tubular; 16 feet long; 60 inches diameter; 48 tubes, 4 inches diameter; 60 pounds pressure; fuel, bituminous coal.

Description of engine: Non-condensing, Worthington duplex; common "D"-valve, operated by opposite rocker-shaft.

Cost of engine and pump: $4,650.

Remarks: Water somewhat unpleasant in hot weather.

MORRISON:

Population: 1,981 inhabitants.

Style of corporation: Municipal.

Water obtained from: Artesian well.

Water first introduced: In 1873.

Description of distributing reservoir: Wooden; built 10 feet above ground; capacity, 90,000 gallons.

Size of distributing mains: 6 inches.

Available head: 65 feet (average).

Length of distributing mains: 660 feet.

Number of water-takers: 40.

Consumption of water: 30,000 gallons per day (estimated).

First cost of water-works: $12,000.

Average annual cost of maintenance and repairs: $1,500.

Number of fire-plugs: 13.

Design and dimensions of pump and water-plunger: Blake No. 8 fire-pump, New York; plain piston-plunger, 7 inches diameter; 12 inches stroke; 40 to 150 strokes per minute; pump-barrel, 7 inches diameter.

Time pump is run: 10 hours per day.

Time spent in repairs: 5 hours per year.

MORRISON—Continued.

Description of water-valves: Puppet.

Kind of power used: Steam.

Description of boilers: Tubular; 12 feet long; 42 inches diameter; 36 tubes, 3 inches diameter; fuel, soft coal.

Description of engine: Simple; cylinder, 12 inches diameter; 12 inches stroke; water-cylinder, 7 inches diameter.

Cost of engine and pump: $700.

SPRINGFIELD:

Population: 19,743 inhabitants.

Name of corporation: Springfield Water-Works (municipal).

Water obtained from: Sangamon river.

Water first introduced: In 1868.

Description of distributing reservoir: Square embankment with rounded corners; 275 feet square at top, 23¾ feet deep; inner slope, 1½ to 1; outer, 2 to 1; puddle facing, 18 inches; stone riprap, 5 inches; bottom, 2 feet of fine clay and 2½ feet of concrete; capacity, 4,000,000 gallons; stand-pipe in center, 75 feet high, 30 inches diameter; wrought iron.

Sizes of distributing mains: 15, 10, 6, and 4 inches.

Total length of distributing mains: 20 miles.

Number of water-takers: 700.

Consumption of water: 1,500,000 to 2,000,000 gallons per day.

First cost of water-works: $450,000.

Average annual cost of maintenance and repairs: $12,000 to $15,000.

Number of fire-plugs: 91.

Design and dimensions of pump and fire-plungers: Built by Worthington, New York, in 1876; plain plungers, 18 inches diameter; 36 inches stroke; 28 strokes per minute.

Time pump is run: 17 hours per day.

Description of force-main: 3¼ miles long; 15 inches diameter; cast iron.

Description of water-valves: Rubber disk; 6 inches diameter; 1½ inch lift.

Kind of power used: Steam.

Description of boilers: Four tubular, 16 feet long, 5 feet diameter; two with 52 tubes, 4 inches diameter; two with 48 tubes, 3½ inches diameter; 60 pounds pressure; fuel used, bituminous coal.

Description of engine: Non-condensing; 29 inches diameter, 36 inches stroke, 28 strokes per minute; slide-valves.

Cost of engine and pump: $13,200 without boilers.

INDIANA.

NEW CARLISLE:

Population: 530 inhabitants.

Style of corporation: Municipal.

Water obtained from: Well.

Water first introduced: In 1879.

Description of distributing reservoir: Wooden tank; 40 feet above ground-level; 103 feet from suction at pump-house.

Sizes of distributing mains: 6 and 4 inches.

Available head: 36 feet (average).

Total length of distributing mains: 7,000 feet.

Consumption of water; 8,000 gallons per day (estimated).

First cost of water-works: $7,000.

Average annual cost of maintenance and repairs: $302 95.

Number of fire-plugs: 13.

Design and dimensions of pump and water-plungers: Built by Worthington, New York; bucket-plungers, 7 inches diameter; pump-barrels, 7 inches diameter.

Time pump is run: One hour per day.

Time spent in repairs: None.

Description of force-main: 6 inches diameter; 40 pounds pressure on pump.

Description of water-valves: Rubber; 3 inches diameter; ½ inch lift.

Kind of power used: Steam.

Description of boiler: 60 pounds pressure.

Description of engine: Non-condensing, 14 by 10 inches; slide-valves.

PERU:

Population: 5,280 inhabitants.
Name of corporation: Peru Water-Works (municipal).
Water obtained from: Wabash river.
Total area of water-shed available: 250 square miles.
Cost of dam: $11,811 52.
Water first introduced: In March, 1879.
Description of main conduit: 370 feet long; 20 inches diameter; iron.
Description of distributing reservoir: Square embankment, 20 feet high; water-level, 16 feet above bottom; embankments all puddled 1 foot thick, and with brick laid without mortar.
Sizes of distributing mains: 16, 12, 10, 8, 6, and 4 inches.
Available head: About 93 feet (average).
Total length of distributing mains: 11 miles and 4,454 feet.
Number of water-takers: 160.
First cost of water-works: $109,549 93.
Average annual cost of maintenance and repairs: About $5,000.
Filtering apparatus: Cleaned once a year.
Number of fire-plugs: 101; various designs.
Design of pump and water-plungers: Built by Worthington, New York, in 1879.
Kind of power used: Steam.
Description of boilers: Nashua steel return-tubular; 16 feet long; 5 feet 4 inches diameter; 65 tubes, 4 inches diameter each; fuel, Indiana block coal.
Cost of engine and pump: $17,902 85.
Duty of engine: 50,000,000 foot-pounds guaranteed.

IOWA.

ANAMOSA:

Population: 2,083 inhabitants.
Name of corporation: Anamosa Water-Works Company (private).
Water obtained from: Wapsipinicon river.
Cost of dam: $600.
Water first introduced: August, 1875.
Description of distributing reservoir: Built with curved sides and square ends; 60 feet long; 14½ feet wide; 15½ feet deep.
Size of distributing mains: 60 inches.
Available head: 75 pounds (average).
Total length of distributing mains: 2 miles.
Number of water-takers: 300.
Consumption of water: 25,000 gallons per day (estimated).
First cost of water-works: $15,000.
Average annual cost of maintenance and repairs: $800.
Number of fire-plugs: 7.
Design and dimensions of pump and water-plungers: Built by Cope & Maxwell, Hamilton, Ohio; bucket-plungers; 10 inches diameter; 36 inches stroke; 25 strokes per minute; pump-barrel, 10 inches diameter.
Time pump is run: 18 hours per week.
Time spent in repairs: 30 hours per year.
Description of force-main: ½ mile long; 6 inches diameter; 75 pounds pressure on pump.
Description of water-valves: Leather; 10 inches diameter.
Kind of power used: Steam.
Description of boiler: Tubular; 40 horse-power; fuel, wood.
Description of engine: Simple; cylinder, 16 inches diameter 34 inches stroke; 25 strokes per minute; slide-valves.
Cost of engine and pump: $2,000.

LYON:

Population: 4,095 inhabitants.
Name of corporation: Lyons Water-Works Company (private).
Water obtained from: Mississippi river.
Capacity of reservoir: 500,000 gallons.
Cost of dam: $2,400.
Water first introduced: March, 1875.
Description of main conduit: 16 inches diameter; cast iron.

LYON—Continued.

Description of distributing reservoir: An excavation on high ground, with massive banking around it; bottom and sides, puddled clay, 18 inches thick; one course of brick laid in water-lime over a rubble and water-lime coating over puddled clay.
Sizes of distributing mains: 12 to 2 inches.
Available head: 110 feet (average).
Total length of distributing mains: 3 miles.
Number of water-takers: 120.
Consumption of water: 150,000 gallons (estimated).
First cost of water-works: $45,000.
Average annual cost of maintenance and repairs: $1,047.
Number of fire-plugs: 37.
Design and dimensions of pumps and water-plungers: Built by Knowles, Warren, Massachusetts, in 1875; plain plungers, 3 feet 10 inches, 25 strokes per minute; pump-barrel, 30 inches diameter. Built by Cope & Maxwell, Detroit, Michigan, in 1874; plain plunger, 12 inches; 40 strokes per minute; pump-barrel, 24 inches diameter.
Time pumps are run: 8 hours; 3 days per week.
Time spent in repairs: 60 hours per year.
Description of force-main: 1,800 feet long; 16 inches diameter; 80 to 130 pounds pressure on pumps.
Description of water-valves: Ludlow.
Kind of power used: Steam.
Description of boilers: Two 3-flue; 90 to 100 pounds pressure.
Description of engine: Simple; cylinder, 24 inches diameter; 24 inches stroke; Ludlow valves.
Cost of engine and pumps: $7,500.
Remarks: During low water the water can not be used for domestic purposes.

OTTUMWA:

Population: 9,004 inhabitants.
Name of corporation: Ottumwa Water-Works (private).
Water obtained from: Des Moines river.
Character and dimensions of dams: Two; stone and wood; 350 feet long; 12 feet deep.
Water first introduced: In 1878.
Description of main conduit: 20 inches diameter; iron.
Discharging capacity: 3,000,000 gallons per day.
Description of distributing reservoir: Built on high elevation.
Sizes of distributing mains: 16 to 4 inches.
Available head: 90 pounds (average).
Total length of distributing mains: 8 miles.
Number of water-takers: 340.
Consumption of water: 75 gallons per head per day (estimated).
Filtering apparatus: Gallery divided into compartments 30 feet square; charcoal; cleaned once a month.
Number of fire-plugs: 76.
Design and dimensions of pumps and water-plungers: Flanders, Vergennes, Vermont; Knowles' steam-pump; four plain plungers; 12 to 30 strokes per minute; pump-barrels, 10, 12, and 14 inches.
Time pumps are run: Constantly.
Description of force-main: 1 mile long; 16 inches diameter; head, 220 feet on pumps.
Description of water-valves: 10 and 12 inches diameter.
Kind of power used: Steam and water.
Description of water-wheels: Eclipse turbine, 72 inches diameter; American turbine, 66 inches diameter; 8 to 10 feet head; about 60 gallons of water required to lift 1 gallon to reservoir.
Description of boiler: Tubular; 70 pounds pressure.
Description of engine: 30 strokes per minute.
Remarks: River is always muddy when the water is high; a slaughter-house above the works imparts a good deal of filth to water.

KENTUCKY.

BOWLING GREEN:

Population: 5,114 inhabitants.
Name of corporation: Bowling Green Water-Works (municipal).
Water obtained from: Barren river.
Water first introduced: In 1868.
Discharging capacity of conduit: Head, 237 feet (average).
Description of distributing reservoir: Oval in shape; on elevation 237 feet above town; capacity, 1,000,000 gallons.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 65 pounds (average).
Total length of distributing mains: 7 miles.
Number of water-takers: 500.
Consumption of water: 300,000 gallons per day, or 60 gallons per head (estimated).
First cost of water-works: $100,000.
Number of fire-plugs: 45.
Design and dimensions of pump and water-plungers: Designed by C. Hennary; built by Dennis Long & Co., Louisville, Kentucky, in 1868; one plain double-acting plunger; 12 inches diameter; 30 inches stroke; 27 strokes per minute; 12 inches diameter pump-barrel.
Time pump is run: 12 hours per day.
Description of force-main: 5,800 feet long; 8 inches diameter; 100 pounds pressure on pumps.
Description of water-valves: Leather.
Kind of power used: Steam.
Description of boilers: Two flue, 20 feet long, 40 inches diameter; one tubular, 14 feet long, 60 inches diameter, 81 flues; fuel, Green River coal.
Description of engine: Simple; 16 inches diameter; 30 inches stroke; 27 strokes per minute.
Cost of pump and engine: $14,000.

MASSACHUSETTS.

ATTLEBOROUGH:

Population: 11,111 inhabitants.
Name of corporation: Attleborough Water-Supply District (municipal).
Water obtained from: Springs.
Water first introduced: In 1874.
Description of distributing reservoir: Wrought iron; 40 feet high; 30 feet deep; inclosed in brick and covered; capacity, about 200,000 gallons.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 26 to 30 pounds.
Total length of distributing mains: 6 miles.
Number of water-takers: 500.
Consumption of water: 50 gallons per head per day (estimated).
First cost of water-works: $60,000.
Number of fire-plugs: 70.
Design and dimensions of pumps and water-plungers: One Blake, Boston; one Worthington, New York, 1874; plain plungers; diameters, 18 and 14 inches.
Time pumps are run: 6 to 8 hours per day.
Time spent in repairs: About 24 hours per year.
Description of force-main: ¼ mile long; 32 pounds pressure on pumps.
Kind of power used: Steam.
Description of boilers: Power rented; fuel, anthracite coal.
Cost of engine and pumps: $1,600.

LAWRENCE:

Population: 39,151 inhabitants.
Style of corporation: Municipal.
Water obtained from: Merrimack river.
Total area of water-shed available: 4,136 square miles.
Water first introduced: December, 1875.
Sizes of distributing mains: 30, 24, 20, 16, 12, 10, 8, and 6 inches.
Available head: 160 feet (average).

LAWRENCE—Continued.

Total length of distributing mains: 42.17 miles.
Number of water-takers: 8,241.
Consumption of water: 681,259,174 gallons in 1880.
First cost of water-works: $1,200,000.
Average annual cost of maintenance and repairs: $15,000.
Filtering apparatus: Gallery, 300 feet long; 8 feet wide; 8 feet high; 15 feet below crest of Essex dam; gravel and sand.
Number of fire-plugs: 464.
Design and dimensions of pump and water-plungers: E. D. Leavitt pump, built by I. P. Morris & Co., Port Richmond Iron-works, Philadelphia, Pennsylvania, in 1875; two bucket-plungers; 18½ inches diameter; 28 inches stroke; 14.64 strokes per minute; pump-barrel, 26½ inches diameter, 8 feet stroke.
Time pump is run: 11 hours 53 minutes per day (average); 305 days per year.
Time spent in repairs; About 40 hours per year.
Description of force-main: 5,000 feet long; 30 inches diameter; head, 180 feet on pump.
Description of water-valves: Double beat; cast-iron case inclosing rubber ring; 16½ inches diameter; ¾ inch lift.
Kind of power used: Steam.
Description of boilers: Two fire-box tubular; 25 feet 5½ inches long; 5 feet 3 inches diameter; 80 tubes, 3 inches diameter each; 90 pounds pressure; evaporation, 11.49 pounds of water to 1 pound of coal.
Description of engine: Compound; high-pressure cylinder, 18 inches diameter; low-pressure cylinder, 38 inches diameter; 8 feet stroke; grid-iron slide-valves worked by revolving "cams." Double-acting air-pump; 15 inches diameter; 28 inches stroke; internal jet-condenser.
Cost of engine and pump: $120,000.
Duty of engine: 102,224,637 foot-pounds in 1880, daily; guaranteed for 95,000,000 foot-pounds.
Remarks: The advantage in pumping to mains is its prompt availability in case repairs are needed in other systems.

PLYMOUTH:

Population: 7,093 inhabitants.
Name of corporation: Plymouth Water-Works (municipal).
Water obtained from: (1) Great, and (2) Little South, ponds; (3) Boot pond; (4) a small lake.
Area of reservoirs: No. 1, 318 acres; No. 2, 54 acres; No. 3, 74 acres; No. 4, 18 acres; all natural reservoirs with artificial connections; no dam required.
Cost of reservoir improvements: $3,000.
Water first introduced: In 1855.
Description of main conduit: 60 feet, 20 inches; 7,300 feet, 10 inches; and 9,200 feet, 10 inches; wrought-iron pipe, coated and lined with cement.
Discharging capacity: 27,000 gallons per hour; head, 16 feet (average).
Description of distributing reservoir: Oblong; 116 by 200 feet; 16 feet deep; slopes, 1½ to 1; bottom and sides clay puddled 1½ feet thick; coat of gravel and sand, 2 feet thick, over which is stone lining, 108 feet above low-water mark; capacity, 1,800,000 gallons.
Sizes of distributing mains: 8 to 2 inches.
Available head: 50 to 90 feet; water-supply deficient for dwellings; relying on pumps.
Total length of distributing mains: 102,291 feet.
Number of water-takers: 1,200.
First cost of water-works: $102,000.
Average annual cost of maintenance and repairs: $3,800.
Filtering apparatus: Only a wire-screen; cleaned once a month.
Number of fire-plugs: 62.
Design and dimensions of pump and water-plungers: Built by H. R. Worthington, New York, in 1879; two plain plungers; 14 inches diameter; 18 inches stroke; 42 strokes per minute; pump-barrel, 20 inches diameter.

PLYMOUTH—Continued.

Time pump is run: 12 hours per day.

Description of force-main: 9,200 feet long; 10 inches diameter; head, 60 feet on pump.

Description of water-valves: Rubber; 6 inches diameter; 1½ inch lift.

Kind of power used: Steam.

Description of boilers: Return tubular; 14 feet long; 4 feet diameter; 30 pounds pressure; fuel, anthracite coal.

Description of engine: Compound condensing; duplex; high-pressure cylinder, 14 inches diameter; low-pressure cylinder, 24½ inches diameter; 18 inches stroke; 84 strokes per minute; slide-valves operated by piston; four bucket air-pumps, 9 inches diameter.

Cost of engine and pump: $7,000.

Duty of engine: 62,424,756 foot-pounds, daily; 50,000,000 foot-pounds guaranteed.

Remarks: Water has a fishy taste and smell sometimes, but this never lasts more than two or three weeks.

WEST NEWTON:

Population: (Population included in Newton.)

Style of corporation: Municipal.

Water obtained from: Charles river.

Area and capacity of reservoir: 126,000 square feet; 1,500,000 gallons.

Water first introduced: In 1876.

Sizes of distributing mains: 16, 12, 8, 6, and 4 inches.

Available head: 60 to 80 pounds.

Total length of distributing mains: 61 miles.

Number of water-takers: 2,261.

Consumption of water: 452,000 gallons per day (estimated).

First cost of water-works: $766,157 22.

Average annual cost of maintenance and repairs: $9,500.

Filtering apparatus: Gallery; gravel; cleaned once a year.

Number of fire-plugs: 324.

Design and dimensions of pump and water-plungers: Built by H. R. Worthington, New York, in 1876; two plain plungers, 21 and 21½ inches diameter; 50 inches stroke; 10 strokes per minute; pump-barrels, 3 feet 4 inches diameter; 10 feet 2 inches long.

Time pump is run: 30 hours per week.

Description of force-main: 21,120 feet long; 20 inches diameter; head, 201.75 feet on pump.

Description of water-valves: Rubber; 9½ inches diameter; 1¼ inch lift.

Kind of power used: Steam.

Description of boilers: Tubular; 20 feet long; 5 feet 5 inches diameter; 50 pounds pressure; evaporation, 8 pounds of water to 1 pound of coal; fuel, hard coal.

Description of engine: Compound condensing; high-pressure cylinder, 30 inches diameter; low-pressure cylinder, 50½ inches diameter; 50 inches stroke; 20 strokes per minute; slide-balance piston-valves by rocker-arm; air-pumps, 2 feet 8 inches diameter; 2 feet stroke; jet-condenser.

Cost of engine and pump: $48,000.

Duty of engine: 63,245,116.1 foot-pounds, daily; 65,000,000 foot-pounds guaranteed.

WOBURN:

Population: 10,931 inhabitants.

Name of corporation: Woburn Water-Works (municipal.)

Total area of water-shed available: 4,760 acres.

Cost of dam: About $50,000.

Water first introduced: September, 1873.

Description of distributing reservoir: Capacity, 5,000,000 gallons; 182 feet above engine-house floor.

Sizes of distributing mains: 14, 12, 10, 8, 6, and 4 inches.

Available head: 65 pounds (average).

Total length of distributing mains: About 37 miles.

Number of water-takers: 2,000.

Consumption of water: About 800,000 gallons, or 75 gallons per head per day (estimated).

WOBURN—Continued.

First cost of water-works: $450,000.

Average annual cost of maintenance and repairs: $8,000.

Filtering apparatus: Gallery, 12 by 82 feet; 5 feet deep (average); connected with pump-wells, 20 feet distant, by 24-inch conduit; loose stone wall; no cleaning.

Number of fire-plugs: 268.

Design and dimensions of pumps and water-plungers: One built by Worthington, New York, in 1873; two plain plungers, 15 inches diameter; 24 inches stroke; 40 strokes per minute; pump-barrel, 21 inches diameter; 4 feet 2 inches long; one built by G. F. Blake, Boston, in 1880.

Time pumps are run: 313 days per year (average).

Time spent in repairs: About 500 hours per year.

Description of force-main: 1,000 feet long; 14 inches diameter; 90 pounds pressure on pumps (average).

Description of water-valves: Rubber; 6-inch size; ⅝ inch lift.

Kind of power used: Steam.

Description of boilers: 16 feet long; 5 feet diameter; 88 tubes, 3 inches diameter; 47 pounds pressure; evaporation, 8½ pounds of water to 1 pound of coal; fuel, Cumberland coal.

Description of engine: Duplex, compound, condensing; high-pressure cylinder, 19¼ inches diameter; low-pressure cylinder, 33⅝ inches diameter; 24 inches stroke; 80 strokes per minute; D-valve operated by rocker-shaft and crank; jet-condenser.

Cost of engine and pumps: About $22,000

Duty of engine: 50,000,000 foot-pounds, daily; 55,000,000 foot-pounds guaranteed.

MICHIGAN.

GRAND RAPIDS:

Population: 32,016 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Two creeks.

Total area of water-shed available: One, 6 square miles; and one 11.5 square miles.

Cost of reservoirs and dam: Distributing reservoir, $54,066 26; settling reservoir, $12,064 35; dam, $50.

Water first introduced: In 1874.

Description of main conduit: 1,993 feet long; 20 inches diameter; iron; head, 20 feet (average).

Description of distributing reservoir: Circular; 196 feet diameter at bottom, 271 feet diameter at top, 25 feet deep; depth of water, 20 feet (average); embankment, earth with puddle walls, 8 feet thick, 21½ feet high in center; capacity, 6,000,000 gallons.

Sizes of distributing mains: 20, 16, 14, 12, 10, 8, 6, and 4 inches.

Available head: 150 feet (average).

Total length of distributing mains: 22.28 miles.

Number of water-takers: 1,200.

Consumption of water: 1,107,424 gallons per day (estimated).

First cost of water-works: $404,296 01.

Average annual cost of maintenance and repairs: $9,000.

Number of fire-plugs: 235; various designs.

Design and dimensions of pump and water-plungers: Turner pump, built by Buteworth & Lowe in 1878; piston-plunger, 15 inches diameter, 15 to 20 strokes per minute; pump-barrel, 14½ by 15 inches.

Description of force-main: 2,578 feet long; 16 inches diameter; head, 150 feet on pump.

Description of water-valves: Rubber-faced; 8 or 10 inches diameter.

Kind of power used: Steam.

Kind of fuel used: Wood.

Description of engine: Horizontal; direct-acting condensing; cylinder, 33 inches diameter; 6 feet stroke; 15 to 20 strokes per minute; balanced puppet-valves; condenser, 3½ feet diameter, 15 feet high.

Cost of engine and pump: $36,534 90.

MISSOURI.

HANNIBAL:

Population: 11,074 inhabitants.
Name of corporation: Hannibal Water Company (private).
Water obtained from: Mississippi river.
Water first introduced: February, 1880.
Description of distributing reservoir: Oval in shape; one-fourth of depth excavated, rest built up; clay, puddled in layers; lined with clay-puddle; bottom and inside slopes paved with rubble-stones; capacity, 1,500,000 gallons.
Sizes of distributing mains: 14 to 6 inches.
Available head: 210 feet (average).
Total length of distributing mains: About 11 miles.
Number of water-takers: 500.
Consumption of water: 130,000 gallons per day (exact).
First cost of water-works: $100,000.
Filtering apparatus: Well; 40 feet deep; 10 feet diameter; 2 layers of gravel and 3 layers sheep's-wool sponges; cleaned 3 or 4 times per year; settling-well, 40 feet deep; 35 feet diameter.
Number of fire-plugs: 75.
Design and dimensions of pump and water-plungers: Built by the Blake Manufacturing Company, Boston, Massachusetts, in 1879; 2 plain plungers; 15 inches diameter; 24 inches stroke; 40 to 50 strokes per minute; pump-barrel, 15 inches diameter.
Time pump is run: 8 hours per day (average).
Description of force-main: 1,500 feet long; 12 inches diameter; head, 220 feet, or 90 pounds pressure on pump.
Description of water-valves: Rubber; 4 inches diameter; ¾ inch lift.
Kind of power used: Steam.
Description of boilers: Tubular; 12 feet long; 64 inches diameter; 3-inch tubes; 60 pounds pressure; fuel, native (Missouri) coal.
Description of engine: Non-condensing simple; cylinder, 24 by 24 inches; 40 to 50 strokes per minute; lever gate-valve.
Cost of engine and pump: $7,000.

SEDALIA:

Population: 9,561 inhabitants.
Style of corporation: Municipal.
Water obtained from: Flat creek.
Character and dimensions of dam: Drop dam; 162 feet long; 4 feet high; stone piers.
Cost of dam: $150,000.
Water first introduced: In 1872.
Description of main conduit: 3 miles long; 12 inches diameter; cast iron.
Description of distributing reservoir: Tank, 30 by 40 feet, placed upon trestle-work 40 feet high; total elevation, 60 feet.
Size of distributing mains: 12 inches.
Available head: 60 feet (average).
Total length of distributing mains: About 18 miles.
Number of water-takers: About 400.
Consumption of water: 25 gallons per head per day (estimated).
First cost of water-works: About $125,000.
Average annual cost of maintenance and repairs: About $7,000.
Number of fire-plugs: 32.
Design and dimensions of pump and water-plungers: Holly; 15 strokes per minute; pump-barrel, 12 inches diameter; 85 pounds pressure.
Time pump is run: 8 hours per day.
Kind of power used: Steam.
Description of engine: Condensing compound; 15 strokes per minute.

NEW JERSEY.

ELIZABETH:

Population: 28,229 inhabitants.
Name of corportion: The Elizabeth Town Water Company (private).
Water obtained from: Elizabeth river.

ELIZABETH—Continued.

Total area of water-shed available: About 40 square miles.
Capacity of reservoir: 100,000,000 gallons.
Character and dimensions of dam: 110 feet long; 12 feet high.
Cost of dam: $200,000; improvements, $75,000.
Water first introduced: March, 1854.
Description of main conduit: To basin, 1 mile long; 24 inches diameter; wrought iron, lined with cement.
Discharging capacity: About 10,000,000 gallons; head 12 feet (average).
Description of distributing reservoir: About 65 feet above tide-water; capacity, 15,000,000 gallons.
Sizes of distributing mains: 24, 20, 16, 12, 10, 6, 4, and 2 inches.
Available head: 60 feet (average); water-supply deficient.
Total length of distributing mains: 40 miles.
Number of water-takers: 2,000.
Consumption of water: 80 gallons per head per day (estimated).
First cost of water-works: $250,000.
Average annual cost of maintenance and repairs: $45,000.
Filtering apparatus: In pumping basin; 150 feet long; 8 feet wide; 8 feet deep; alternate layers of gravel, sand, and charcoal; cleaned once in two years.
Number of fire-plugs: 200.
Design and dimensions of pumps and water-plungers: Built by Hewet A. Phillips and L. B. Battus, Newark, 1854, Elizabeth, 1874; plain plungers, packed with leather, 12, 14, and 20 inches diameter; 48 inches stroke; two, 30 strokes per minute, and one, 16 strokes per minute; pump-barrel, 12, 14, and 20 inches diameter.
Time pumps are run: 15 hours per day.
Time spent in repairs: 168 hours per year.
Description of force-main: 24 inches diameter; 25 pounds pressure on pumps.
Description of water-valves: Circular, 6 inches diameter; square strips of rubber in one; rings of rubber in one; conical strips on one; about ½ inch lift.
Kind of power used: Steam and water.
Description of water-wheel: One turbine, 54 inches diameter; 12 feet head; 90 revolutions per minute; 17 gallons of water required to lift 1 gallon to reservoir.
Description of boilers: Four, horizontal tubular; 16 feet long; 4½ feet diameter; evaporation, 10 pounds of water to 1 pound of coal; fuel, No. 2 chestnut coal.
Description of engines: Condensing; one, 18 inches diameter; 4 feet stroke; one, 24 inches diameter; 4 feet stroke; 30 strokes per minute; D-valve, with cut-off at ½ inch stroke; air-pumps, single-acting, induction butterfly; eduction in the piston; jet-condenser.
Cost of engines and pumps: $10,000.

NEW YORK.

BUFFALO:

Population: 155,134 inhabitants.
Name of corporation: Buffalo Water-Works (municipal).
Water obtained from: Niagara river.
Water first introduced: In 1851.
Description of distributing reservoir: Embankment of earth, 600 by 300 feet; 21 feet deep; slopes, inner, 1 to 1—outer, 1½ to 1; width at top, 13 feet; puddle-faced to depth of 12 inches; ripraped with brick.
Sizes of distributing mains: 16, 12, 10, 8, 6, and 4 inches.
Total length of distributing mains: 103 miles.
Available head: Holly system, 40 pounds pressure; head from reservoir, 90 feet (average).
Number of water-takers: 9,000.
Consumption of water: 18,000,000 gallons per day.
First cost of water-works: $705,000.
Average annual cost of maintenance and repairs: $58,255.
Number of fire-plugs: 1,118.

BUFFALO—Continued.

Design and dimensions of pumps and water-plungers: Two sets built by Holly Manufacturing Company, Lockport, New York, in 1868 and 1877; plain piston-plungers, half of them 14 inches diameter, 24 inches stroke—the rest, 15½ inches diameter, 33½ inches stroke; 36 to 40 strokes per minute. Two Worthington, New York, 1874–'77; plain plungers; 4 feet stroke; 40 strokes per minute. One built by Sheppard, Buffalo, New York, in 1867; plain piston-plunger; 32½ inches diameter; 10 feet stroke; 16 strokes per minute.

Time pumps are run: Holly, constantly; Worthington, both sets, total, 418 days; Sheppard, seldom.

Time spent in repairs: Variable.

Description of force-main: 3,000 feet long; 30 and 36 inches diameter; 42 pounds pressure on Holly pumps, 30 pounds pressure on others.

Kind of power used: Steam.

Description of boilers: 3 Worthington multitubular, 18 feet long, 5 feet diameter, 58 4-inch tubes, 35 pounds pressure. Four marine, 16 feet long, 8 feet diameter, 120 4-inch tubes; one 14 feet long, 9 feet diameter, 130 3-inch tubes. Fuel, anthracite coal.

Description of engines: Sheppard's—condensing cylinder, 65 inches diameter; 10 feet stroke; 16 strokes per minute; double-beat valves by cams and plug-rods; air-pump, 32½ inches by 4 feet; jet-condenser, 4 by 4 feet. Holly—non-condensing or compound cylinders, 14 and 15½ inches diameter; 24 and 32½ inches strokes; 36 to 40 strokes per minute; condenser, 5 by 18 inches; air-pumps, 20 by 18 inches stroke. Worthington—compound; 40 strokes per minute; jet-condenser, 3 by 6 feet; air-pumps, 24 by 24 inches and 18 by 24 inches.

Cost of engines and pumps. Sheppard, $28,000; Holly, $46,500; Worthington, $91,000.

Duty of engines: Sheppard, 45,000,000 foot-pounds, daily; Holly, 85,000,000 foot-pounds, daily; Worthington, 45,000,000 foot-pounds, daily.

Remarks: Pumping used because no site sufficiently elevated for reservoir is available.

ROME:

Population: 12,194 inhabitants.

Name of corporation: Rome Water Company (municipal).

Water obtained from: Mohawk river.

Capacity of reservoir: 10,000,000 gallons.

Cost of dam: $20,000.

Water first introduced: In 1872.

Sizes of distributing mains: 16, 12, 10, 8, and 4 inches.

Available head: 25 pounds (average).

Total length of distributing mains: 16 miles.

Number of water-takers: 600.

Consumption of water: 900,000 gallons per day (estimated).

First cost of water-works: $160,000.

Average annual cost of maintenance and repairs: $2,500.

Number of fire-plugs: 125.

Design and dimensions of pump and water-plungers: Built by Watertown Steam-Engine Company, Watertown, New York; plain plungers, 12 by 24 inches; 1 foot diameter; 24 strokes per minute.

Time pump is run: 14 hours per day.

Description of force-main: Head, 65 feet; 20 pounds pressure on pump.

Description of water-valves: Double-seated brass; size, 12 inches; 1¾ inch lift.

Kind of power used: Water.

Description of water-wheels: Two turbines, 6 feet diameter; made by Helmer & Harris, Rome, New York; 8 feet head; 16 revolutions per minute.

PENNSYLVANIA.

BETHLEHEM:

Population: 5,193 inhabitants.

Name of corporation: Bethlehem Borough Water-Works (municipal).

BETHLEHEM—Continued.

Water obtained from: Spring.

Cost of dam: $20,300.

Description of main conduit: 16,000 feet long; 8, 6, 4, and 3 inches diameter; iron.

Discharging capacity: 777,700 gallons per day.

Description of distributing reservoir: Capacity of tank, 167,000 gallons; filled from mains.

Sizes of distributing mains: 8, 6, 4, and 3 inches.

Available head: 149 feet (average); water-supply deficient.

Total length of distributing mains: 16,000 feet.

Consumption of water: 167,000 gallons per day (estimated).

First cost of water-works: $20,300.

Average annual cost of maintenance and repairs: $1,500.

Design and dimensions of pumps and water-plungers: Cameron patent, New York, 1874; plain plungers; one steam, 12 inches diameter, 36 inches stroke, 15 strokes per minute; one water, 48 inches stroke, 5½-inch plunger, 10 strokes per minute; pump-barrel, 12 inches diameter.

Time pumps are run: Water, constantly; steam, 6 hours per day.

Kind of power used: Steam and water.

Description of water-wheel: One undershot; 8 feet diameter; 20 feet long; 22 inches head; 10 revolutions per minute.

Description of boilers: 35 feet long; 3 feet diameter; 40 pounds pressure; fuel, coal screenings.

Description of engine: Non-condensing; cylinder, 24 inches diameter; 36 inches stroke; 12 strokes per minute; slide-valves self-operated.

Cost of engine and pumps: $6,000.

Remarks: Water is fresh from the spring; pressure is good.

BLOOMSBURG:

Population: 3,702 inhabitants.

Name of corporation: The Bloomsburg Water Company (private).

Water obtained from: Fishing creek.

Cost of reservoir: $6,000.

Water first introduced: In September, 1880.

Description of distributing reservoir: Built by excavation and embankment; lined with clay and paved with brick; 82 feet 6 inches square at bottom; 127 feet 6 inches square at top; capacity, 1,000,000 gallons.

Sizes of distributing mains: 10, 8, 6, and 4 inches.

Available head: About 150 feet (average).

Total length of distributing mains: 4½ miles.

Number of water-takers: 94.

Consumption of water: 260 gallons (estimated).

First cost of water-works: $36,000.

Number of fire-plugs: 40.

Design and dimensions of pumps and water-plungers: Berkenbine pumps; built by Camden Iron Works; plain plunger; one for each; 6½ inches diameter; 20 inches stroke; 50 to 60 strokes per minute; pump-barrel, 6½ to 20 inches.

Time pumps are run: 2 hours per day.

Description of force-main: 1,050 feet long; 8 inches diameter; 80 pounds pressure on pumps.

Description of water-valves: Berkenbine, double-beat, water-cushioned; ¾ inch lift.

Kind of power used: Steam.

Description of boilers: Two upright tubular; 6 feet long; 5 feet diameter; fire-box, 4 feet high; 157 2-inch flues.

Description of engine: High-pressure; cylinder, 12 inches diameter; 20 inches stroke; 50 to 60 strokes per minute; slide-valves by rock-shaft.

Cost of engine and pumps: $2,300.

Remarks: The advantage and disadvantage of direct pumping are that as a fire protection it is a great success, but is not so for ordinary consumers.

CHAMBERSBURG:

Population: 6,877 inhabitants.

Name of corporation: City Water-Works (municipal).

Water obtained from: Mountain stream.

CHAMBERSBURG—Continued.

Capacity of reservoir: 110,000 gallons.
Cost of dam: $55,000.
Water first introduced: July, 1876.
Description of distributing reservoir: Built on heavy slate, clay puddled, and lined with brick laid in sand; 100 feet above center of town.
Sizes of distributing mains: 10, 8, 6, and 4 inches.
Available head: 100 feet or 40 pounds (average).
Total length of distributing mains: 7 miles.
Number of water-takers: 450.
Consumption of water: 6 gallons per head per day (estimated).
First cost of water-works: $55,000.
Average annual cost of maintenance and repairs: $150.
Number of fire-plugs: 60.
Design and dimensions of pump and water-plungers: H. M. Berkenbine pump, Lebanon, Pennsylvania; built by Mount Wisner Manufacturing Company; one plain plunger, 14 inches diameter; 36 inches stroke; 35 strokes per minute; pump-barrel, 14 by 36 inches.
Description of force-main: 2,000 feet long; 48 pounds pressure on pump.
Description of water-valves: Cast iron; size, 12 inches; 2 inches lift.
Kind of power used: Steam.
Description of boilers: Flue; 14 feet long; 60 inches diameter; 60 pounds pressure; fuel, bituminous coal.
Description of engine: Simple; cylinder, 16 inches diameter; 30 inches stroke; 35 strokes per minute; plain slide-valves, link motion; air-chamber, 18 by 48 inches.
Remarks: The advantage of direct pumping is manifest in case of fire, as there are no engines in town.—Water good, except after heavy rains.

MEDIA:

Population: 1,919 inhabitants.
Style of corporation Municipal.
Water obtained from: Ridley creek.
Total area of water-shed available: About 25 square miles.
Capacity of reservoir: 1,300,000 gallons.
Character and dimensions of dam: Built of stone, filled in back with gravel; 6 feet high; 120 feet long.
Cost of dam: $14,000.
Water first introduced: In October, 1872.
Description of main conduit: 800 feet long; 12 inches diameter; cast iron.
Description of distributing reservoir: 16 feet deep; 130 feet 7½ inches square on top, 87 feet square on bottom; a dividing embankment across the middle, with 12-inch inlets.
Sizes of distributing mains: 8, 6, 4, and 2 inches.
Available head: 50 to 75 feet.
Total length of distributing mains: 24,000 feet.
Number of water-takers: 261.
Consumption of water: 40 gallons per head per day (estimated).
First cost of water-works: $80,000.
Average annual cost of maintenance and repairs: $300.
Number of fire-plugs: 10.
Design and dimensions of pump and water-plungers: Built by I. S. Cassin, Philadelphia, Pennsylvania; plain plungers; 7 inches diameter; 48 inches stroke; 12 strokes per minute (average); pump-barrels, 7 inches diameter.
Description of force-main: 4,800 feet long, 8 inches diameter; 2,450 feet long, 6 inches diameter; difference of level is 248.8 feet.
Description of water-valves: Brass.
Kind of power used: Steam and water.
Description of water-wheel: Leffel turbine; 35 inches diameter; 10½ feet head; 124 revolutions per minute; about 350 gallons required to lift 1 gallon to reservoir.
Description of boiler: Upright tubular; 20 horse-power.
Remarks: The disadvantage of pumping direct to mains is that the water is muddy after rains.

POTTSTOWN:

Population: 5,305 inhabitants.
Name of corporation: Pottstown Gas and Water Company (private).
Water obtained from: Schuylkill river.
Total area of water-shed available: 2,000 square miles.
Water first introduced: In 1870.
Description of main conduit: 5,000 feet long; 10 inches diameter; head, 140 feet.
Description of distributing reservoir: Built in two sections, nearly square, on a hill; partly excavated and partly embankment; puddled with clay; lined with brick laid in cement and cemented over; capacity, 1,600,000 gallons; water not filtered, but run through a screen.
Sizes of distributing mains: 8, 6, and 4 inches.
Available head: 90 to 120 feet.
Total length of distributing mains: 7 miles.
Number of water-takers: 490.
First cost of water-works: About $85,000.
Average annual cost of maintenance and repairs: About $3,000.
Number of fire-plugs: 45.
Design and dimensions of pump and water-plungers: Henderson pump, built by Philadelphia Hydraulic Works; two plain plungers, 8 inches diameter; 24 inches stroke; 25 strokes per minute; pump-barrel, 8 inches diameter.
Time pump is run: 4 hours per week.
Description of force-main: About 65 pounds pressure on pump.
Description of water-valves: Brass.
Kind of power used: Steam.
Description of boilers: Tubular.
Description of engine: Condensing; cylinder, 10 inches diameter; 24 inches stroke; 25 strokes per minute.
Cost of engine and pump: $11,000.
Remarks: The advantage of pumping direct to mains is reduction of expense for pipes; the disadvantage consists mainly in this that consumers are supplied with muddy water from river.

TENNESSEE.

MEMPHIS:

Population: 33,592 inhabitants.
Name of corporation: Memphis Water Company (private).
Water obtained from: Wolf river.
Water first introduced: In 1873.
Description of distributing reservoir: Earthen embankment, with puddle face and brick riprap; 16 feet deep; slopes, 1½ to 1; capacity, 3,500,000 gallons.
Sizes of distributing mains: 20, 18, 16, 14, 12, 10, 8, 6, 4, and 3 inches.
Total length of distributing mains: 28 miles.
Number of water-takers: 2,759.
Consumption of water: 4,500,000 gallons per day.
First cost of water-works: $450,000.
Average annual cost of maintenance and repairs: $20,000.
Number of fire-plugs: 184.
Design and dimensions of pumps and water-plungers: Holly, in 1873; gang of 8 operated by 2-cylinder engine; 8 plain single-acting lift-plungers; 20 inches diameter; 24 inches stroke; 15 strokes per minute; pump-barrel, 20 by 36 inches.
Time pumps are run: Constantly.
Description of force-main: 2 miles long; 20 inches diameter; cast iron.
Description of water-valves: Rubber disk; 16 inches; 3 inches lift.
Kind of power used: Steam.
Description of boilers: Three multitubular; 16 feet long; 70 inches diameter; 120 3-inch tubes in each; 60 to 70 pounds pressure; fuel, best soft coal.

MEMPHIS—Continued.

Description of engine: Non-condensing; 2 cylinders; 20 inches diameter; 33 inches stroke; 37½ strokes per minute; slide-valves.

Duty of engine: 32,000,000 foot-pounds, daily.

Remarks: New engines are being built.

TEXAS.

SAN ANTONIO:

Population: 20,550.

Name of corporation: San Antonio Water-Works Company (private).

Water obtained from: San Antonio river.

Capacity of reservoir: 5,000,000 gallons.

Cost of dam: $150,000.

Water first introduced: In July, 1878.

Description of main conduit: 2 miles and 4,100 feet long; 12 inches diameter; cast iron; head, 154 feet (average).

Description of distributing reservoir: 200 feet square; 20 feet deep.

Sizes of distributing mains: 10, 8, and 6 inches.

Available head: 60 pounds (average).

Total length of distributing mains: About 12 miles.

Number of water-takers: 565.

Consumption of water: 800,000 gallons per day (estimated).

First cost of water-works: $125,000.

Average annual cost of maintenance and repairs: About $10,000.

Number of fire-plugs: 100.

Design and dimension of pump and water-plungers: Built by Worthington, New York; two pair plungers; 14 inches diameter; 10½ inches stroke; 40 strokes per minute; pump-barrels, 14 by 10½ inches.

Time pump is run: About 14 hours per day.

Description of water-valves: Rubber; 5 inches diameter.

Kind of power used: Water.

Description of water-wheels: Two, 72 inches diameter; Eclipse double turbines; built by Stillwell & Beirce, Dayton, Ohio; 8 feet head; 30 revolutions per minute.

WISCONSIN.

MENOMONEE:

Population: 4,177 inhabitants.

Name of corporation: The Knapp, Stout & Co. Company (private).

Water obtained from: Red Cedar river.

Total area of water-shed available: 1,620 square miles.

Capacity of reservoir: 152,000 gallons.

Character and dimensions of dam: 400 feet long; 11 feet head; across Red Cedar river.

Cost of dam: $10,000.

Water first introduced: In 1876.

Description of main conduit: Ayerault wooden pipe; 400 feet, 2,500 feet, and 600 feet long; 8, 4, and 6 inches diameter, respectively.

Discharging capacity: 750 gallons per minute; head, 100 feet and 150 feet.

Description of distributing reservoir: Brick and stone; set on a hill 185 feet high; 24 by 60 feet and 14 feet deep; covered.

Sizes of distributing mains: 8, 6, and 4 inches.

Available head: 100 feet (average).

Total length of distributing mains: 3,900 feet.

First cost of water-works: $10,000.

Average annual cost of maintenance and repairs: $150.

Number of fire-plugs: 14.

Design and dimensions of pump and water-plungers: Built by Worthington, Pittsburgh, Pennsylvania, 1876; duplex; two plain plungers; 10 by 7 inches; 80 strokes per minute; pump-barrel, 20 by 20 inches and 16 inches.

Time pump is run: Six hours per day.

Time spent in repairs: 48 hours per year.

Description of force-main: 1,400 feet long; 80 pounds pressure on pump.

Description of water-valves: Rubber; 4 inches diameter. One Eclipse, 72 inches diameter; built by Stillwell & Beirce; vents 303 square inches water; 12 feet head; 20 revolutions per minute.

Kind of power used: Water.

WATER-WORKS EMPLOYING SYSTEM OF PUMPING TO STAND-PIPE AND DISTRIBUTING MAINS.

ILLINOIS.

WILMINGTON:

Population: 1,872 inhabitants.
Style of corporation: Municipal.
Water obtained from: Branch of Kankakee river.
Character and dimensions of dams: Across river, 1,006 feet long, 16 feet high; across branch, 700 feet long, 5 feet high.
Cost of dams: $400,000.
Water first introduced: In 1877.
Description of main conduit: 6 inches diameter; cast iron.
Sizes of distributing mains: 6 and 4 inches.
Total length of distributing mains: About 5,000 feet.
First cost of water-works: $5,000.
Number of fire-plugs: 3.
Design and dimensions of pumps and water-plungers: Holly, No. 7; two rotary pumps, Nos. 4 and 7.
Kind of power used: Water.
Description of water-wheel: Leffel turbine; 54 inches diameter; 8 feet head; 75 revolutions per minute.
Remarks: Water only used for fire purposes.

IOWA.

CLINTON:

Population: 9,052 inhabitants.
Name of corporation: Clinton Water-Works Company (private).
Water obtained from: Mississippi river.
Water first introduced: In 1874.
Description of stand-pipe: 100 feet high; contains 13,500 gallons.
Sizes of distributing mains: 16 to 4 inches.
Available head: 100 feet (average).
Total length of distributing mains: 8 miles.
Number of water-takers: 352.
Consumption of water: 550,000 gallons per day (estimated).
First cost of water-works: $120,000.
Average annual cost of maintenance and repairs: $4,500.
Filtering apparatus: Use boxes filled with sand and gravel; cleaned twice a year.

CLINTON—Continued.

Number of fire-plugs: 85.
Design and dimensions of pumps and water-plungers: Built by Cope & Maxwell, Ohio, in 1874; 3 plain plungers, 10 inches diameter; 28 inches stroke; 33 strokes per minute; pump-barrel, 10 by 28 inches. Pressure on pumps—domestic use, 50 pounds; for fire, 100 pounds.
Time pumps are run: One constantly.
Description of water-valves: Rubber; 8 inches diameter; 2 inches lift.
Kind of power used: Steam.
Description of boilers: Two; 16 feet long; 5 feet diameter; 13 6-inch flues.
Description of engine: Non-condensing; cylinder, 16 inches diameter; 28 inches stroke.
Cost of engine and pumps: $13,500.

TEXAS.

HOUSTON:

Population: 16,513 inhabitants.
Name of corporation: Houston Water-Works Company (private).
Water obtained from: Buffalo bayou.
Character and dimensions of dam: Small one below works to keep out tide-water from bay.
Water first introduced: April, 1879.
Description of stand-pipe: 86 feet high; 20 feet diameter.
Sizes of distributing mains: 12, 10, 8, 6, and 4 inches.
Available head: 30 pounds (average); water-supply deficient when it is low in stand-pipe.
Total length of distributing mains: 13 miles.
Number of water-takers: 350.
Consumption of water: 250,000 gallons per day (estimated).
First cost of water-works: $75,000.
Average annual cost of maintenance and repairs: From $5,000 to $10,000, including extensions.
Number of fire-plugs: 91.
Design and dimensions of pump and water-plungers: Built by H. R. Worthington, New York.

WATER-WORKS EMPLOYING THE GRAVITY SYSTEM AND PUMPING TO DISTRIBUTING RESERVOIR AND STAND-PIPE.

DISTRICT OF COLUMBIA.

WASHINGTON:

Population: 147,293 inhabitants.

Style of corporation: Owned by United States and District of Columbia.

Water obtained from: Potomac river.

Character and dimensions of dam: One at Great Falls; built of rubble and solid masonry.

Cost of dam: $3,784,546.72 expended by the United States; $1,313,315.17 expended by Washington; $40,000 expended by Georgetown.

Water first introduced: In 1858.

Description of main conduit: 9 miles long; 9 feet diameter; brick.

Discharging capacity: 30,000,000 per 24 hours; head, 145 feet (average).

Description of stand-pipe: 52 feet high; 32 feet diameter.

Sizes of distributing mains: 36, 30, and 12 inches.

Water-supply: Deficient.

Total length of distributing mains: 175 miles and 3,777½ feet.

WASHINGTON—Continued.

Consumption of water: 26,000,000 gallons per day, or 176 gallons per head per day (estimated).

Average annual cost of maintenance and repairs: $70,000.

Number of fire-plugs: 825.

Design and dimensions of pumps and water-plungers: One Knowles; one Blake, built in New York; 3 plain plungers; 15 inches diameter; 24 inches stroke; 36 strokes per minute.

Time pumps are run: Constantly.

Time spent in repairs: About 180 hours per year.

Description of force-main: 3,000 feet long.

Description of water-valves: Rubber; 4 inches size; 2½ inches lift.

Kind of power used: Steam.

Description of boilers: 25 pounds pressure; fuel, Cumberland coal.

Description of engines: Condensing compound; 36 strokes per minute; slide and oval valves operated by steam; condenser, 6 by 12.

Cost of engines and pumps: $12,000.

WATER-WORKS EMPLOYING THE GRAVITY SYSTEM AND PUMPING TO DISTRIBUTING RESERVOIR AND MAINS.

MISSOURI.

KANSAS CITY:

Population: 55,785 inhabitants.

Name of corporation: National Water-Works Company of New York (private).

Water obtained from: Kansas river.

Water first introduced: In 1874.

Description of main conduit: 1,350 feet long; 24 inches diameter; siphon-pipe.

Discharging capacity: About 8,000,000 gallons per day.

Description of distributing reservoir: Clay embankment laid in 1-foot depths and rolled; bottom, concrete, 9 inches thick; sides paved with limestone 12 to 18 inches thick; dimensions, 300 by 330 feet; water, 21 feet deep; elevation flow-line, 236 feet; capacity, 10,000,000 gallons.

Sizes of distributing mains: 15, 12, 10, 8, 6, and 4 inches.

Available head: 60 to 250 feet.

Total length of distributing mains: About 25 miles.

Number of water-takers: About 1,700.

Consumption of water: 2,070,000 gallons per day (exact).

Average annual cost of maintenance and repairs: $23,000.

Filtering apparatus: Water stands two or three days in subsiding reservoir to allow sediment to settle, then passes through wall of finely broken stone; cleansed twice a year; capacity, 10,000,000 gallons.

Number of fire-plugs: 265.

Design and dimensions of pumps and water-plungers: Built by the Holly Manufacturing Company, Lockport, New York; part piston and part plungers; two ,15½ inches diameter, 30 inches stroke; four, 10 inches diameter, 30 inches stroke; four, 7¾ inches diameter, 22 inches stroke; four, 10½ inches diameter, 33 inches stroke; two, 21 inches diameter, 34 inches stroke; 20 to 40 strokes per minute.

Time pumps are run: Constantly.

Description of force-mains; One, 2,390 feet, 20 inches diameter, 90 pounds pressure on pumps; the other, 4,567 feet long, 20 inches diameter, 135 pounds pressure on pumps.

Description of water-valves: Low-service, rubber disks, 5¼ inches diameter, ⅝ inch lift; high-service, brass breast, 3 by 10 inches, ⅝ inch lift; brass puppet, rubber seats, 1¼ inch diameter, 1¼ inch lift.

Kind of power used: Steam.

Description of boilers: Return tubular; 16 feet long; 5½ feet diameter; 52 3½ inch flues; grate surface, 22 feet each; 100 square feet coal surface.

Description of engines: One set compound condensing, 21 by 30 inches each; one single condensing, 16 by 27 inches; one set of 4 compound condensing, 27 by 33 inches each; 20 to 40 strokes per minute; slide puppet-valves; cut-off variable, on top of steam-chest; two single-acting air-pumps to each set; jet-condenser.

KANSAS CITY—Continued.

Duty of engines: Old, 10,000,000 foot-pounds guaranteed; new, 8,000,000 foot-pounds guaranteed.

Remarks: The advantage of pumping to mains consists in the supplying of heights not covered by reservoir; the disadvantage is that constant action is required.

NEW JERSEY.

LAMBERTVILLE:

Population: 4,183 inhabitants.

Name of corporation: Lambertville Water Company (private).

Water obtained from: Trap-dike (Goat hill) and Delaware river.

Total area of water-shed available: 1,000 acres.

Capacity of reservoir: 6,097,577 gallons.

Character and dimensions of dam: 200 feet long; 9 feet high.

Cost of dam: $22,471 55.

Water first introduced: November, 1878.

Available head: 164 feet (average).

Number of water-takers: 111.

Description of water-valves: Rubber.

Kind of power used: Steam.

Description of boilers: Tubular; fuel, anthracite, Jeddo mines, Lehigh.

Cost of engine and pump: $1,656 25.

Remarks: The advantage of pumping to mains is that when water is required for fire or for house use it is received quickly.—Vegetable matter is troublesome in reservoir; water otherwise good.

NEW YORK.

SYRACUSE:

Population: 51,792 inhabitants.

Name of corporation: Syracuse Water-Works (private).

Water obtained from: Brooks, springs, and creek.

Character and dimensions of dam: Earth; back slope, 2½ to 1; front slope, 2 to 1; width on top, 15 feet; front slope faced 15 inches dry wall, backed with 9-inch lining; puddle wall in center, 6 feet wide on top, increasing 11 inches, 6 feet vertical depth.

Water first introduced: In 1849.

Sizes of distributing mains: 30, 24, 12, 10, 8, 6, and 4 inches.

Available head: 122 to 165 feet.

Total length of distributing mains: 40 miles.

Number of water-takers: 1,125.

Consumption of water: 4,000,000 gallons per day (average).

First cost of water-works: $605,000.

SYRACUSE—Continued.

Average annual cost of maintenance and repairs: $13,000.

Number of fire-plugs: 270.

Design and dimensions of pump and water-plungers: Two plain, hollow, air-tight plungers; 30 inches diameter; 50 inches stroke; 25 strokes per minute; pump-barrel, 36 inches diameter.

Time pump is run: 8 hours per day.

Description of water-valves: Rubber; 10 inches diameter; 1¼ inch lift; in chambers above and below plungers.

Kind of power used: Steam.

774

SYRACUSE—Continued.

Description of boilers: Horizontal tubular; 16 feet long; 5 feet diameter; 60 4-inch tubes; 50 pounds pressure; evaporation, 7 pounds of water to 1 pound of coal.

Description of engines: Duplex compound condensing; 2 high-pressure cylinders, 29 inches diameter; 2 low-pressure cylinders, 50¼ inches diameter; 50 inches stroke; 25 strokes per minute; balance D-valve, operated by opposite engine; jet-condenser; 4 air-pumps, 23 inches diameter, 24 inches stroke, bucket type.

Duty of engines: 52,000,000 foot-pounds, daily.

WATER-WORKS EMPLOYING THE GRAVITY SYSTEM AND PUMPING TO STAND-PIPE AND DIRECT INTO DISTRIBUTING MAINS.

PENNSYLVANIA.

TIOGA:

Population: 520 inhabitants.

Name of corporation: T. A. & C. H. Wickham (private).

Water obtained from: Bently creek.

Total area of water-shed available: About 1 square mile.

Capacity of reservoir: 12,000,000 gallons.

Character and dimensions of dam: On creek; 270 feet long on top; 30 feet high; greatest depth, 25 feet; made of earth, with clay puddling starting from sheet-piling of foundation.

Cost of dam and reservoir: Dam, $2,100; reservoir, $3,500.

Water first introduced: December, 1874.

Description of main conduit: 6, 4, and 3 inches diameter; Wyckoff's patent wooden pipe.

Discharging capacity: 500 gallons per minute; head, 113.7 feet (average).

TIOGA—Continued.

Description of distributing reservoir: Excavated; size, 80 by 90 feet at water-line; lined with masonry wall faced with brick; slopes, 1 to 4 and 1 to 2½; depth of water over discharge-pipe, 16 feet; capacity, 750,000 gallons.

Sizes of distributing mains: 6, 4, and 3 inches.

Available head: 210 feet (average).

Total length of distributing mains: 15,500 feet.

Number of water-takers: 63.

Consumption of water: 250,000 gallons per day (estimated).

First cost of water-works $20,000.

Average annual cost of maintenance and repairs: $20.

Filtering apparatus: One set galleries at reservoir; sand and gravel; cleaning depends on storms.

Number of fire-plugs: 14.

Design and dimensions of pumps and water-plungers: One La France, Elmira, New York; pumping done outside.

WATER-WORKS EMPLOYING SYSTEM OF PUMPING TO DISTRIBUTING RESERVOIR, STAND-PIPE, AND MAINS.

MASSACHUSETTS.

NEW BEDFORD:

Population: 26,845 inhabitants.
Name of corporation: New Bedford Water-Works (municipal).
Water obtained from: Acushnet river.
Total area of water-shed available: About 3,300 acres.
Capacity of reservoir: About 300,000,000 gallons.
Character and dimensions of dam: 600 feet long; 20 feet wide; slopes, 2 to 1; top, 4 feet above high-water; 15 feet deep; gravel puddle-wall, and loam cut and cross-cut with spade.
Cost of dam: $18,845 24; improvements, $45,556 72.
Water first introduced: January, 1870.
Description of main conduit: 5⅝ miles long; egg shape; 3 feet by 4 feet; brick.
Discharging capacity: 11,664,000 gallons; head, 8 feet 8 inches (average).
Description of distributing reservoir: Rectangular earth embankment; 15 feet wide on top; slopes, 2 to 1; 17 feet deep; water-surface, 3½ acres; capacity, 14,000,000 gallons.
Sizes of distributing mains: 24 to 4 inches.
Available head: 90 feet, or 62 pounds (average); water-supply deficient.
Total length of distributing mains: 42.27 miles.
Number of water-takers: 3,798.
First cost of water-works: $526,000.
Average annual cost of maintenace and repairs: About $14,000.
Number of fire-plugs: 295.
Design and dimensions of pumps and water-plungers: Two. No. 1, McAlpine; Morgan Iron Works, New York, in 1868–'69; single-acting; 2 pistons; 28 inches diameter; 4 feet 8 inches stroke; 28 strokes per minute; pump-barrel, 28 inches diameter. No. 2, Worthington, New York, 1873–'74; 2 plain plungers, 17½ inches diameter; 36 inches stroke; 30 strokes per minute; pump-barrel, 17½ inches diameter.
Time pumps are run: No. 1, 3,060 hours; No. 2, 281 hours in 1880.
Time spent in repairs: About 200 hours per year.
Description of force-main: 2,200 feet long; 16 inches diameter; head, 122 feet on pumps.
Description of water-valves: No. 1, butterfly, 12 by 27 inches; No. 2, rubber disk, 7 inches diameter.
Kind of power used: Steam.
Description of boilers. Horizontal return tubular; 18 feet long, 6 feet diameter; 90 3½-inch tubes in each; 30 pounds pressure; fuel, Wilkesbarre broken coal.
Description of engines: No. 1, condensing, simple; cylinder, 36 inches diameter; 8 feet stroke; 27 strokes per minute; puppet-valve, Sickles cut-off; air-pump, 27 by 34 inches; jet condenser, 5 by 4 feet. No. 2, condensing compound; high-pressure cylinder, 21⅝ inches diameter; low-pressure cylinder, 36 inches diameter; 36 inches stroke; 60 strokes per minute. Worthington valves and jet-condenser.
Cost of engines and pumps: No. 1, $37,457 33; No. 2, $17,000.

NEW BEDFORD—Continued.

Duty of engines: No. 1, 45,159,704 foot-pounds, daily; 60,000,000 foot-pounds guaranteed. No. 2, 34,050,875 foot-pounds, daily.
Remarks: A bed of peat under reservoir discolors water slightly.

PENNSYLVANIA.

CATASAUQUA:

Population: 3,065 inhabitants.
Name of corporation: Crane Iron Company (private).
Water obtained from: Lehigh river.
Water first introduced: In 1843.
Description of main conduit: Open feeder, 1,200 feet long; 25 feet wide; 7 feet deep.
Description of distributing reservoir and stand-pipe: 50 feet square; 12 feet deep; earthen banks; brick, laid in cement; stand-pipe, 120 feet high, 48 inches diameter at bottom, 36 inches diameter at top.
Sizes of distributing mains: 12, 10, 8 inches.
Available head: 15 to 40 pounds.
Total length of distributing mains: 2 miles.
Number of water-takers: 258.
First cost of water-works: $6,300.
Average annual cost of maintenance and repairs: $100.
Number of fire-plugs: 3.
Design and dimensions of pump and water-plungers: Home made; two plain double-acting pistons; 8 inches diameter; 36 inches stroke; 8 strokes per minute; pump-barrel, 8 inches diameter.
Time pump is run: Constantly.
Description of force-main: 100 feet long; 65 pounds pressure on pumps.
Description of water-valves: Gum disk; size, 11½ inches; lift, 1 inch.
Kind of power used: Water.
Description of water-wheel: 12 feet diameter; 3 feet head; 24 revolutions per minute.

ERIE:

Population: 27,737 inhabitants.
Name of corporation: City Water-Works (municipal).
Water obtained from: Lake Erie.
Cost of dams: $702,391 58.
Water first introduced: In 1868.
Description of main conduit: 1,400 feet long.
Description of distributing reservoir and stand-pipe: 28 feet deep; capacity, 33,000,000 gallons; stand-pipe, 250 feet high; made of iron, surrounded by a brick tower.
Sizes of distributing mains: 20, 12, 6, and 4 inches.
Available head: 100 to 200 feet.
Total length of distributing mains: 35 miles.
Number of water-takers: About 3,500.
Consumption of water: 77 gallons per head.
First cost of water-works: $675,000.

ERIE—Continued.

Average annual cost of maintenance and repairs: $19,397 45.

Number of fire-plugs: 130.

Design and dimensions of pumps and water-plungers: Built by West Engine Company, Norristown, Pennsylvania; 10 strokes per minute; pump-barrels, 10 feet by 21 inches.

Time pumps are run: Constantly.

Description of force-main: 2 miles long; 20 inches diameter.

Description of water-valves: Crown; 27 inches diameter; receiving-lift, 2 inches; delivery-lift, 1½ inch.

ERIE—Continued.

Kind of power used: Steam.

Description of boilers: Horizontal tubular; 60 pounds pressure; evaporation about 6 to 1; fuel, bituminous coal.

Description of engine: Condensing simple-acting; 60 inches diameter; 120 inches stroke; 10 strokes per minute; crown-valves operated by springs; air-pump single; jet-condenser; volume of air-pump, 25.9 feet.

Cost of engines and pumps: $55,000.

Duty of engine: 24,628,000 foot-pounds, daily.

INDEX TO REPORT ON WATER-SUPPLY OF CITIES.

A.

Page.

Additional supply of water at Boston water-works 25–27
Agawam, Mass 178, 179
Alabama:
Birmingham 246
Mobile 243
Albany, N. Y 94–96
Albany, Oreg 232
Allegan, Mich 223
Allegheny, Pa 205
Allentown, Pa 244
Alpena, Mich 223
Alton, Ill 246–247
Altoona, Pa 188
Anamosa, Iowa 248
Ansonia, Conn 175
Archbald, Pa 188
Arkansas:
Little Rock 212
Arlington, Mass 179
Ashland, Pa 188
Athol, Mass 179
Atlanta, Ga 217
Attica, Ind 197
Attica, N. Y 184, 185
Attleborough, Mass 249
Auburn, Me 178
Auburn, N. Y 227
Augusta, Ga 212
Austin, Nev 183
Austin, Tex 210, 211
Avon, N. Y 185

B.

Baltimore, Md 235, 236
Bangor, Me 122–124
Basins, filtering 2
Batavia, N. Y 227
Bay City, Mich 223, 224
Bellaire, Ohio 204, 205
Bellefonte, Pa 238
Bellows Falls, Vt 193
Belmont works, Philadelphia, Pa 134, 135
Belvidere, N. J 214
Bethel, Conn 175
Bethlehem, N. H 184
Bethlehem, Pa 252
Biddeford, Me 199
Big Rapids, Mich 224
Birmingham, Ala 246
Birmingham, Conn 175, 176
Black River Falls, Wis 233
Bloomington, Ill 57, 58
Bloomsburg, Pa 252
Boston, Mass 17–31
Bowling Green, Ky 249
Brandon, Vt 193
Brazil, Ind 219
Bridgeton, N. J 201

Page.

Bristol, Pa 214
Brookline, Mass 243
Brooklyn, N. Y 83–90
Buffalo, N. Y 251, 252
Burlington, Iowa 50–55
Burlington, N. J 236
Burlington, Vt 211
Butler, Pa 205

C.

Cadillac, Mich 224
California:
Chico 216
Dutch Flat 173
Grass Valley 173
Los Angeles 173
Marysville 195
Mission San José 173
Oakland 173
Petaluma 173, 174
Placerville 174
Sacramento 216
San Diego 195
San Francisco 234
San José 174
San Rafael 174
Santa Barbara 174
Santa Clara 174
Truckee 174
Vallejo 234
Washington 174, 175
Watsonville 175
Yreka 175
Cambridge, Mass 243, 244
Canajoharie, N. Y 237
Cañon City, Colo 195
Canton, Pa 188
Cape May, N. J 201, 202
Carbondale, Pa 188
Caribou, Colo 175
Carlisle, Pa 205, 206
Catasauqua, Pa 260
Cedar Rapids, Iowa 221
Chambersburg, Pa 252, 253
Charleston, S. C 214, 215
Chattanooga, Tenn 210
Chelsea, Mass 236
Chester, Pa 206
Chestnut Hill works, Philadelphia, Pa 141
Chicago, Ill 69
Chico, Cal 216
Chicopee, Mass 179
Cincinnati, Ohio 101–111
Clarion, Pa 206
Clarksville, Tenn 240
Cleveland, Ohio 112, 113
Clinton, Iowa 255
Coatesville, Pa 189
Cohoes, N. Y 203

Page.
College Point, N. Y 227
Colorado:
Cañon City 195
Caribou 175
Colorado Springs 175
Denver 216
Leadville 234, 235
Pueblo 217
Trinidad 195, 196
Colorado Springs, Colo 175
Columbia, Pa 238
Columbus, Ind 219, 220
Columbus, Ohio 47–50
Combinations of various systems 125–171
Comparison of systems 2
Concord, N. H 43, 44
Connecticut:
Ansonia 175
Bethel 175
Birmingham 175, 176
Danbury 176
Greenwich 176
Hartford 32–34
Meriden 176
New Britain 176
New Haven 97–99
New London 38–40
New Milford 176
Norwich 41–43
Rockville 176, 177
Shelton 177
Simsbury 177
South Norwalk 177
Stamford 177
Waterbury 177
West Winsted 177
Windsor 177
Wolcottville 177, 178
Connersville, Ind 220
Constantine, Mich 224
Cooperstown, N. Y 227
Corning, N. Y 237

D.

Dakota:
Deadwood 178
Dallas, Oreg 188
Dallas, Tex 215
Danbury, Conn 176
Danvers, Mass 199
Danville, Pa 232
Danville, Va 211
Davenport, Iowa 221
Dayton, Ohio 230
Deadwood, Dak 178
Decatur, Ill 217
De Kalb, Ill 196
Delaware:
New Castle 196
Wilmington 196
Delaware works, Philadelphia, Pa 135–137
Delhi, N. Y 185
Denver, Colo 216
Des Moines, Iowa 221
Detroit, Mich 65–69
Direct pumping 46–56
Distributing reservoir, Parker Hill, Boston, Mass, water-works 28–30
District of Columbia:
Washington 256
Dorchester, Mass 236
Dover, N. H 184
Downington, Pa 189
Dunkirk, N. Y 227, 228
Dunmore, Pa 189
Dutch Flat, Cal 173

E.

Page.
East Liverpool, Ohio 205
East Saginaw, Mich 224, 225
Elizabeth, N. J 251
Ellenville, N. Y 185
Elmira, N. Y 237
Emporia, Kans 222, 223
Ephrata, Pa 189
Erie, Pa 260, 261
Eureka, Nev 183
Evansville, Ind 220

F.

Fair Haven, Vt 193
Fairmount water-works, Philadelphia, Pa 127–131
Fall River, Mass 213
Fayetteville, N. C 187
Filtering basins 2
Fitchburg, Mass 179
Florida:
Jacksonville 246
Fond du Lac, Wis 194
Fort Wayne, Ind 197
Frankford works, Philadelphia, Pa 137–139
Franklin, Pa 189
Frostburg, Md 178

G.

Garden City, N. Y 228
Geneseo, Ill 217, 218
Geneva, N. Y 185
Georgia:
Atlanta 217
Augusta 212
Macon 178
Rome 196
Savannah 212
Gettysburg, Pa 189
Glens Falls, N. Y 185
Gloversville, N. Y 185
Goshen, N. Y 185
Gouverneur, N. Y 228
Grand Rapids, Mich 250
Grass Valley, Cal 173
Gravity system 5–45, 173–194
Gravity system and pumping direct into distributing mains 241, 242
Gravity system and pumping to distributing reservoir 234–239
Gravity system and pumping to distributing reservoir and mains 257, 258
Gravity system and pumping to distributing reservoir and stand-pipe 256
Gravity system and pumping to stand-pipe 240
Gravity system and pumping to stand-pipe and direct into distributing mains 259
Greenfield, Mass 179
Greenwich, Conn 176

H.

Hannibal, Mo 251
Hanover, N. H 184
Hanover, Pa 189
Harrisburg, Pa 206
Hartford, Conn 32–34
Haverhill, Mass 236
Hazleton, Pa 189
Hingham, Mass 179
Hollidaysburg, Pa 189, 190
Holly, Mich 225
Holyoke, Mass 179, 180
Houston, Tex 255
Hudson, N. Y 203
Hyde Park, Ill 218

I.

Illinois:
Alton 246, 247
Bloomington 57, 58
Chicago 69
Decatur 217

Illinois—Continued. Page.
De Kalb 196
Geneseo 217, 218
Hyde Park 218
Jacksonville 247
Lake 218
Lockport 197
Moline 218
Morrison 247
Oregon 235
Peoria 56
Quincy 197
Ravenswood 218, 219
Rochelle 219
Springfield 247
Stockyard Station 219
Sycamore 219
Wilmington 255
Illustrations 3
Indiana:
Attica 197
Brazil 219
Columbus 219, 220
Connersville 220
Evansville 220
Fort Wayne 197
Indianapolis 46, 47
La Fayette 197, 198
Logansport 220
Marion 220
New Albany 198
New Carlisle 247
Peru 248
South Bend 213
Terre Haute 213
Union City 220, 221
Indianapolis, Ind 46, 47
Introduction 1–3
Iowa:
Anamosa 248
Burlington 50–55
Cedar Rapids 221
Clinton 255
Davenport 221
Des Moines 221
Keokuk 221, 222
Lyon 248
Marengo 222
Marshalltown 222
Monticello 222
Muscatine 235
Oskaloosa 222
Ottumwa 248
Ironton, Ohio 230

J.

Jackson, Mich 225
Jacksonville, Fla 246
Jacksonville, Ill 247
Jersey City, N. J 202
Johnstown, Pa 190
Jordan, N. Y 228

K.

Kansas:
Emporia 222, 223
Kansas City, Mo 257
Keene, N. H 184
Kennett Square, Pa 206, 207
Kenosha, Wis 194
Kentucky:
Bowling Green 249
Louisville 80–82
Maysville 198
Newport 198, 199
Owensborough 223
Pleasant Hill 199

Page
Keokuk, Iowa 221, 222
Kingston, Mass 199, 200
Kittanning, Pa 207

L.

Lacrosse, Wis 233
La Fayette, Ind 197, 198
Lake, Ill 218
Lambertville, N. J 257
Lancaster, Ohio 214
Lancaster, Pa 207
Lawrence, Mass 249
Leadville, Colo 234, 235
Lebanon, Pa 190
Leominster, Mass 180
Lewiston, Me 199
Lewistown, Pa 238
Lincoln, Mass 200
Little Rock, Ark 212
Lockport, Ill 197
Lockport, N. Y 228
Logan, Utah 193
Logansport, Ind 220
Long Island City, N. Y 229
Los Angeles, Cal 173
Louisiana:
New Orleans 153, 154
Louisville, Ky 80–82
Lowell, Mass 114–117
Lynn, Mass 200
Lyon, Iowa 248
Lyons, N. Y 203, 204

M.

Macon, Ga 178
Mahanoy City, Pa 190
Maine:
Auburn 178
Bangor 122–124
Biddeford 199
Lewiston 199
Portland 40, 41
Skowhegan 178
Springvale 178
Malden, Mass 180
Malone, N. Y 185, 186
Manchester, N. H 118–122
Mankato, Minn 226
Mansfield, Ohio 230, 231
Marengo, Iowa 222
Marion, Ind 220
Marquette, Mich 225
Marshalltown, Iowa 222
Martinsburg, W. Va 232, 233
Maryland:
Baltimore 335, 236
Frostburg 178
Marysville, Cal 195
Massachusetts:
Agawam 178, 179
Arlington 179
Athol 179
Attleborough 249
Boston 17–31
Brookline 243
Cambridge 243, 244
Chelsea 236
Chicopee 179
Danvers 199
Dorchester 236
Fall River 213
Fitchburg 179
Greenfield 179
Haverhill 236
Hingham 179

Massachusetts—Continued. Page.
Holyoke ... 179, 180
Kingston ... 199, 200
Lawrence ... 249
Leominster ... 180
Lincoln ... 200
Lowell ... 114–117
Lynn ... 200
Malden ... 180
Medford ... 180
Melrose ... 180
Nantucket ... 213, 214
New Bedford ... 260
Northampton ... 180
Northfield ... 180, 181
Peabody ... 181
Pittsfield ... 181
Plymouth ... 249, 250
Salem ... 99–101
Somerville ... 200
South Adams ... 181
Southbridge ... 181
South Hadley Falls ... 181
Springfield ... 34–38
Stockbridge ... 181
Taunton ... 223
Uxbridge ... 183
Waltham ... 200, 201
Westborough ... 181, 182
Westfield ... 182
West Newton ... 250
West Springfield ... 182
West Stockbridge ... 182
Williamstown ... 182
Winchester ... 182
Woburn ... 250
Worcester ... 182
Maysville, Ky ... 198
Meadville, Pa ... 207
Mechanicsburg, Pa ... 190
Medford, Mass ... 180
Media, Pa ... 253
Melrose, Mass ... 180
Memphis, Tenn ... 253, 254
Menomonee, Wis ... 254
Meriden, Conn ... 176
Michigan:
Allegan ... 223
Alpena ... 223
Bay City ... 223, 224
Big Rapids ... 224
Cadillac ... 224
Constantine ... 224
Detroit ... 65–69
East Saginaw ... 224, 225
Grand Rapids ... 250
Holly ... 225
Jackson ... 225
Marquette ... 225
Muskegon ... 225
Niles ... 183
Port Huron ... 225, 226
Saginaw ... 226
Saint Louis ... 226
Middletown, N. Y ... 186
Millville, N. J ... 214
Milwaukee, Wis ... 244, 245
Minersville, Pa ... 190
Minneapolis, Minn ... 226
Minnesota:
Mankato ... 226
Minneapolis ... 226
Saint Paul ... 183
Stillwater ... 240
Mission San José, Cal ... 173

Missouri: Page.
Hannibal ... 251
Kansas City ... 257
Saint Joseph ... 201
Saint Louis ... 144–152
Sedalia ... 251
Mobile, Ala ... 243
Moline, Ill ... 218
Monticello, Iowa ... 222
Morrison, Ill ... 247
Morristown, N. J ... 184
Mount Holly, N. J ... 202
Mount Joy, Pa ... 207, 208
Mount Morris, N. Y ... 186
Muscatine, Iowa ... 235
Muskegon, Mich ... 225
Mystic department of Boston, Mass., water-works ... 24, 25

N.

Nantucket, Mass ... 213, 214
Nashua, N. H ... 201
Nashville, Tenn ... 78, 79
Nebraska:
Omaha ... 241
Nevada:
Austin ... 183
Eureka ... 183
Pioche ... 183
Reno ... 183
Virginia City ... 183, 184
New Albany, Ind ... 198
Newark, N. J ... 236, 237
New Bedford, Mass ... 260
New Britain, Conn ... 176
Newburg, N. Y ... 186
New Carlisle, Ind ... 247
New Castle, Del ... 196
New Hampshire ... 118–122
Bethlehem ... 184
Concord ... 43, 44
Dover ... 184
Hanover ... 184
Keene ... 184
Nashua ... 201
Portsmouth ... 184
New Haven, Conn ... 97–99
New Jersey:
Belvidere ... 214
Bridgeton ... 201
Burlington ... 236
Cape May ... 201, 202
Elizabeth ... 251
Jersey City ... 202
Lambertville ... 257
Millville ... 214
Morristown ... 184
Mount Holly ... 202
Newark ... 236, 237
Passaic ... 202
Paterson ... 202, 203
Rahway ... 226, 227
Trenton ... 203
New Lisbon, Ohio ... 187
New London, Conn ... 38–40
New Milford, Conn ... 176
New Orleans, La ... 153, 154
Newport, Ky ... 198, 199
New York:
Albany ... 94–96
Attica ... 184, 185
Auburn ... 227
Avon ... 185
Batavia ... 227
Brooklyn ... 83–90
Buffalo ... 251, 252

New York—Continued. Page.
Canajoharie 237
Cohoes 203
College Point 227
Cooperstown 227
Corning 237
Delhi 185
Dunkirk 227, 228
Ellenville 185
Elmira 237
Garden City 228
Geneva 185
Glens Falls 185
Gloversville 185
Goshen 185
Gouverneur 228
Hudson 203
Jordan 228
Lockport 228
Long Island City 229
Lyons 203, 204
Malone 185, 186
Middletown 186
Mount Morris 186
Newburg 186
New York 5–17
Niagara Falls 229
Ogdensburg 229
Olean 229
Oswego 204
Peekskill 204
Plattsburg 186
Port Byron 237, 238
Port Jervis 186
Potsdam 229
Poughkeepsie 167–171
Richfield Springs 186
Rochester 154–160
Rome 252
Saratoga Springs 229, 230
Schenectady 230
Syracuse 257, 258
Troy 160–163
Utica 186, 187
Walton 187
Warsaw 187
Warwick 187
Waverly 187
West Troy 204
Yonkers 241
New York, N. Y 5–17
Niagara Falls, N. Y 229
Niles, Mich 183
Norfolk, Va 232
Norristown, Pa 208
Northampton, Mass 180
North Carolina:
Fayetteville 187
Northfield, Mass 180, 181
Norwalk, Ohio 231
Norwich, Conn 41–43

O.

Oakland, Cal 173
Ogdensburg, N. Y 229
Ohio:
Bellaire 204, 205
Cincinnati 101–111
Cleveland 112, 113
Columbus 47–50
Dayton 230
East Liverpool 205
Ironton 230
Lancaster 214
Mansfield 230, 231
New Lisbon 187

Ohio—Continued. Page.
Norwalk 231
Portsmouth 231
Sandusky 58–62
Sidney 231
Toledo 62–65
Urbana 231
West Cleveland 244
Wooster 187, 188
Youngstown 231, 232
Zanesville 244
Oil City, Pa 208
Olean, N. Y 229
Olympia, Wash 239
Omaha, Nebr 241
Oregon:
Albany 232
Dallas 188
Oregon, Ill 235
Oskaloosa, Iowa 222
Oswego, N. Y 204
Ottumwa, Iowa 248
Owensborough, Ky 223
Oxford, Pa 208

P.

Parker Hill distributing reservoir, Boston, Mass., water-works 28–30
Parker's Landing, Pa 209
Passaic, N. J 202
Paterson, N. J 202, 203
Pawtucket, R. I 163–167
Peabody, Mass 181
Peekskill, N. Y 204
Pennsylvania:
Allegheny 205
Allentown 244
Altoona 188
Archbald 188
Ashland 188
Bellefonte 238
Bethlehem 252
Bloomsburg 252
Bristol 214
Butler 205
Canton 188
Carbondale 188
Carlisle 205, 206
Catasauqua 260
Chambersburg 252–253
Chester 206
Clarion 206
Coatesville 189
Columbia 238
Danville 232
Downington 189
Dunmore 189
Ephrata 189
Erie 260, 261
Franklin 189
Gettysburg 189
Hanover 189
Harrisburg 206
Hazleton 189
Hollidaysburg 189, 190
Johnstown 190
Kennett Square 206, 207
Kittanning 207
Lancaster 207
Lebanon 190
Lewistown 238
Mahanoy City 190
Meadville 207
Mechanicsburg 190
Media 253
Minersville 190
Mount Joy 207, 208

Pennsylvania—Continued. Page.
Norristown 208
Oil City 208
Oxford 208
Parker's Landing 209
Philadelphia 125–144
Phœnixville 209
Pittsburgh 90–94
Pittston 209
Plymouth 190–191
Pottstown 253
Pottsville 191
Reading 191
Renovo 191
Saint Petersburg 209
Scranton 191
Sewickley 191
Shamokin 242
Slatington 191
South Bethlehem 240
Stroudsburg 191, 192
Summit Hill 209, 210
Susquehanna 192
Tidioute 192
Tioga 259
Titusville 232
Towanda 192
Tremont 192
Tunkhannock 192
Westchester 210
Wilkesbarre 192, 242
Williamsport 192, 193
York 210
Peoria, Ill 56
Peru, Ind 248
Petaluma, Cal 173, 174
Philadelphia, Pa 125–144
Phœnixville, Pa 209
Pioche, Nev 183
Pittsburgh, Pa 90–94
Pittsfield, Mass 181
Pittston, Pa 209
Placerville, Cal 174
Plattsburg, N. Y 186
Pleasant Hill, Ky 199
Plymouth, Mass 249, 250
Plymouth, Pa 190, 191
Port Byron, N. Y 237, 238
Port Huron, Mich 225, 226
Port Jervis, N. Y 186
Portland, Me 40, 41
Portsmouth, N. H 184
Portsmouth, Ohio 231
Potsdam, N. Y 229
Pottstown, Pa 253
Pottsville, Pa 191
Poughkeepsie, N. Y 167–171
Prairie du Chien, Wis 194
Providence, R. I 70–77
Pueblo, Colo 217
Pumping by water-power 118–124
Pumping direct into distributing mains 216–233
Pumping direct into distributing mains, and gravity system 241, 242
Pumping direct to reservoir 83–117
Pumping through stand-pipe—surplus to reservoir 70–77
Pumping through stand-pipe to reservoir 78
Pumping to distributing reservoir 195–211
Pumping to distributing reservoir, and gravity system 234–239
Pumping to distributing reservoir and mains 246–254
Pumping to distributing reservoir and mains, and gravity system 257, 258
Pumping to distributing reservoir and stand-pipe 243–245
Pumping to distributing reservoir and stand-pipe, and gravity system 256
Pumping to distributing reservoir, stand-pipe, and mains 260, 261
Pumping to stand-pipe 57–69, 212–215
Pumping to stand-pipe and gravity system 240
Pumping to stand-pipe and direct into distributing mains 255
Pumping to stand pipe and direct into distributing mains, and gravity system 259
Purity of waters 3

Q.

Quincy, Ill 197

R.

Rahway, N. J 226, 227
Ravenswood, Ill 218, 219
Reading, Pa 191
Reno, Nev 183
Renovo, Pa 191
Rhode Island:
Pawtucket 163–167
Providence 70–77
Westerly 193
Richfield Springs, N. Y 186
Rochelle, Ill 219
Rochester, N. Y 154–160
Rockville, Conn 176, 177
Rome, Ga 196
Rome, N. Y 252
Roxborough works, Philadelphia, Pa 139–141
Rutland, Vt 44, 45

S.

Sacramento, Cal 216
Saginaw, Mich 226
Saint Albans, Vt 193, 194
Saint Johnsbury, Vt 242
Saint Joseph, Mo 201
Saint Louis, Mich 226
Saint Louis, Mo 144–152
Saint Paul, Minn 183
Saint Petersburg, Pa 209
Salem, Mass 99–101
Salt Lake City, Utah 193
San Antonio, Tex 254
San Diego, Cal 195
San Francisco, Cal 234
San José, Cal 174
San Rafael, Cal 174
Sandusky, Ohio 58–62
Santa Barbara, Cal 174
Santa Clara, Cal 174
Saratoga Springs, N. Y 229, 230
Savannah, Ga 212
Schenectady, N. Y 230
Schuylkill works, Philadelphia, Pa 131–134
Scranton, Pa 191
Sedalia, Mo 251
Sewickley, Pa 191
Shamokin, Pa 242
Shelton, Conn 177
Sidney, Ohio 231
Simsbury, Conn 177
Skowhegan, Me 178
Slatington, Pa 191
Somerville, Mass 200
South Adams, Mass 181
South Bend, Ind 213
South Bethlehem, Pa 240
Southbridge, Mass 181
South Carolina:
Charleston 214, 215
South Hadley Falls, Mass 181
South Norwalk, Conn 177
Springfield, Ill 247
Springfield, Mass 34–38
Springvale, Me 178
Stamford, Conn 177
Staunton, Va 238, 239
Stillwater, Minn 240
Stockbridge, Mass 181
Stockyard Station, Ill 219

Page.
Stroudsburg, Pa 191, 192
Summit Hill, Pa 209, 210
Supply of water, additional, at Boston, Mass., water-works 25–27
Susquehanna, Pa 192
Sycamore, Ill 219
Syracuse, N. Y 257, 258
Systems, comparison of 2

T.

Taunton, Mass 223
Tennessee:
Chattanooga 210
Clarksville 240
Memphis 253, 254
Nashville 78, 79
Terre Haute, Ind 213
Texas:
Austin 210, 211
Dallas 215
Houston 255
San Antonio 254
Tidioute, Pa 192
Tioga, Pa 259
Titusville, Pa 232
Toledo, Ohio 62–65
Towanda, Pa 192
Tremont, Pa 192
Trenton, N. J 203
Trinidad, Colo 195, 196
Troy, N. Y 160–163
Truckee, Cal 174
Tunkhannock, Pa 192

U.

Union City, Ind 220, 221
University of Virginia, Va 194
Urbana, Ohio 231
Utah:
Logan 193
Salt Lake City 193
Utica, N. Y 186, 187
Uxbridge, Mass 183

V.

Vallejo, Cal 234
Vermont:
Bellows Falls 193
Brandon 193
Burlington 211
Fair Haven 193
Rutland 44, 45
Saint Albans 193, 194
Saint Johnsbury 242
Virginia:
Danville 211
Norfolk 232
Staunton 238, 239
University of Virginia 194
Winchester 194
Virginia City, Nev 183, 184

W.

Walla-Walla, Wash 194
Waltham, Mass 200, 201
Walton, N. Y 187
Warsaw, N. Y 187
Warwick, N. Y 187
Washington:
Olympia 239
Walla-Walla 194
Washington, Cal 174, 175
Washington, D. C 256
Waterbury, Conn 177
Water-pipes 1, 2
Waters, purity of 3
Water-supply, additional, at Boston., Mass., water-works 25, 27

Water-works employing the gravity system: Page.
Agawam, Mass 178, 179
Altoona, Pa 188
Ansonia, Conn 175
Archbald, Pa 188
Arlington, Mass 179
Ashland, Pa 188
Athol, Mass 179
Attica, N. Y 184, 185
Auburn, Me 178
Austin, Nev 183
Avon, N. Y 185
Bellows Falls, Vt 193
Bethel, Conn 175
Bethlehem, N. H 184
Birmingham, Conn 175, 176
Boston, Mass 17–31
Brandon, Vt 193
Canton, Pa 188
Carbondale, Pa 188
Caribou, Colo 175
Chicopee, Mass 179
Coatesville, Pa 189
Colorado Springs, Colo 175
Concord, N. H 43, 44
Dallas, Oreg 188
Danbury, Conn 176
Deadwood, Dak 178
Delhi, N. Y 185
Dover, N. H 184
Downington, Pa 189
Dunmore, Pa 189
Dutch Flat, Cal 173
Ellenville, N. Y 185
Ephrata, Pa 189
Eureka, Nev 183
Fair Haven, Vt 193
Fayetteville, N. C 187
Fitchburg, Mass 179
Fond du Lac, Wis 194
Franklin, Pa 189
Frostburg, Md 178
Geneva, N. Y 185
Gettysburg, Pa 189
Glens Falls, N. Y 185
Gloversville, N. Y 185
Goshen, N. Y 185
Grass Valley, Cal 173
Greenfield, Mass 179
Greenwich, Conn 176
Hanover, N. H 184
Hanover, Pa 189
Hartford, Conn 32–34
Hazleton, Pa 189
Hingham, Mass 179
Hollidaysburg, Pa 189, 190
Holyoke, Mass 179, 180
Johnstown, Pa 190
Keene, N. H 184
Kenosha, Wis 194
Lebanon, Pa 190
Leominster, Mass 180
Logan, Utah 193
Los Angeles, Cal 173
Macon, Ga 178
Mahanoy City, Pa 190
Malden, Mass 180
Malone, N. Y 185, 186
Mechanisburg, Pa 190
Medford, Mass 180
Melrose, Mass 180
Meriden, Conn 176
Middletown, N. Y 186
Minersville, Pa 190
Mission San José, Cal 173
Morristown, N. J 184

Water-works employing the gravity system—Continued. Page.
Mount Morris, N. Y 186
New Britain, Conn 176
Newburg, N. Y 186
New Haven, Conn 97–99
New Lisbon, Ohio 187
New London, Conn 38–40
New Milford, Conn 176
New York, N. Y 5–17
Niles, Mich 183
Northampton, Mass 180
Northfield, Mass 180, 181
Norwich, Conn 41–43
Oakland, Cal 173
Peabody, Mass 181
Petaluma, Cal 173, 174
Pioche, Nev 183
Pittsfield, Mass 181
Placerville, Cal 174
Plattsburg, N. Y 186
Plymouth, Pa 190, 191
Port Jervis, N. Y 186
Portland, Me 40, 41
Portsmouth, N. H 184
Pottsville, Pa 191
Prairie du Chien, Wis 194
Reading, Pa 191
Reno, Nev 183
Renovo, Pa 191
Richfield Springs, N. Y 186
Rochester, N. Y 154–160
Rockville, Conn 176, 177
Rutland, Vt 44, 45
Saint Albans, Vt 193, 194
Saint Paul, Minn 183
Salt Lake City, Utah 193
San José, Cal 174
San Rafael, Cal 174
Santa Barbara, Cal 174
Santa Clara, Cal 174
Scranton, Pa 191
Sewickley, Pa 191
Shelton, Conn 177
Simsbury, Conn 177
Skowhegan, Me 178
Slatington, Pa 191
South Adams, Mass 181
Southbridge, Mass 181
South Hadley Falls, Mass 181
South Norwalk, Conn 177
Springfield, Mass 34–38
Springvale, Me 178
Stamford, Conn 177
Stockbridge, Mass 181
Stroudsburg, Pa 191, 192
Susquehanna, Pa 192
Tidioute, Pa 192
Towanda, Pa 192
Tremont, Pa 192
Troy, N. Y 160–163
Truckee, Cal 174
Tunkhannock, Pa 192
University of Virginia, Va 194
Utica, N. Y 186, 187
Uxbridge, Mass 183
Virginia City, Nev 183, 184
Walla-Walla, Wash 194
Walton, N. Y 187
Warsaw, N. Y 187
Warwick, N. Y 187
Washington, Cal 174, 175
Waterbury, Conn 177
Watsonville, Cal 175
Waverly, N. Y 187
Westborough, Mass 181, 182
Westerly, R. I 193

Water-works employing the gravity system—Continued. Page.
Westfield, Mass 182
West Springfield, Mass 182
West Stockbridge, Mass 182
West Winsted, Conn 177
Wilkesbarre, Pa 192
Williamsport, Pa 192, 193
Williamstown, Mass 182
Winchester, Mass 182
Winchester, Va 194
Windsor, Conn 177
Wolcottville, Conn 177, 178
Wooster, Ohio 187, 188
Worcester, Mass 182
Yreka, Cal 175

Water-works employing the gravity system and pumping direct into distributing mains:
Omaha, Nebr 241
Rochester, N. Y 154–160
Saint Johnsbury, Vt 242
Shamokin, Pa 242
Troy, N. Y 160–163
Wilkesbarre, Pa 242
Yonkers, N. Y 241

Water-works employing the gravity system and pumping to distributing reservoir:
Baltimore, Md 235, 236
Bellefonte, Pa 238
Boston, Mass 17–31
Burlington, N. J 236
Canajoharie, N. Y 237
Chelsea, Mass 236
Columbia, Pa 238
Corning, N. Y 237
Dorchester, Mass 236
Elmira, N. Y 237
Hartford, Conn 32–35
Haverhill, Mass 236
Leadville, Colo 234, 235
Lewistown, Pa 238
Muscatine, Iowa 235
Newark, N. J 236, 237
New Haven, Conn 97–99
Olympia, Wash 239
Oregon, Ill 235
Port Byron, N. Y 237, 238
Saint Louis, Mo 144–152
San Francisco, Cal 234
Staunton, Va 238, 239
Vallejo, Cal 234

Water-works employing the gravity system and pumping to distributing reservoir and mains:
Kansas City, Mo 257
Lambertville, N. J 257
Syracuse, N. Y 257, 258

Water-works employing the gravity system and pumping to distributing reservoir and stand-pipe:
Washington, D. C 256

Water-works employing the gravity system and pumping to stand-pipe:
Clarksville, Tenn 240
South Bethlehem, Pa 240
Stillwater, Minn 240

Water-works employing the gravity system and pumping to stand-pipe and direct into distributing mains:
Tioga, Pa 259

Water-works employing the system of pumping direct into distributing mains:
Albany, Oreg 232
Allegan, Mich 223
Alpena, Mich 223
Atlanta, Ga 217
Auburn, N. Y 227
Bangor, Me 122–124
Batavia, N. Y 227
Bay City, Mich 223, 224
Big Rapids, Mich 224

Water-works employing the system of pumping direct into distributing mains—Continued. Page.

Black River Falls, Wis 233
Brazil, Ind 219
Burlington, Iowa 50-55
Cadillac, Mich 224
Cedar Rapids, Iowa 221
Chico, Cal 216
College Point, N. Y 227
Columbus, Ind 219, 220
Columbus, Ohio 47-50
Connersville, Ind 220
Constantine, Mich 224
Cooperstown, N. Y 227
Danville, Pa 232
Davenport, Iowa 221
Dayton, Ohio 230
Decatur, Ill 217
Denver, Colo 216
Des Moines, Iowa 221
Dunkirk, N. Y 227, 228
East Saginaw, Mich 224, 225
Emporia, Kans 222, 223
Evansville, Ind 220
Garden City, N. Y 228
Geneseo, Ill 217, 218
Gouverneur, N. Y 228
Holly, Mich 225
Hyde Park, Ill 218
Indianapolis, Ind 46, 47
Ironton, Ohio 230
Jackson, Mich 225
Jordan, N. Y 228
Keokuk, Iowa 221, 222
Lacrosse, Wis 233
Lake, Ill 218
Lockport, N. Y 228
Logansport, Ind 220
Long Island City, N. Y 229
Mankato, Minn 226
Mansfield, Ohio 230, 231
Marengo, Iowa 222
Marion, Ind 220
Marquette, Mich 225
Marshalltown, Iowa 222
Martinsburg, W. Va 232, 233
Minneapolis, Minn 226
Moline, Ill 218
Monticello, Iowa 222
Muskegon, Mich 225
Niagara Falls, N. Y 229
Norfolk, Va 232
Norwalk, Ohio 231
Ogdensburg, N. Y 229
Olean, N. Y 229
Oskaloosa, Iowa 222
Owensborough, Ky 223
Peoria, Ill 56
Port Huron, Mich 225, 226
Portsmouth, Ohio 231
Potsdam, N. Y 229
Pueblo, Colo 217
Rahway, N. J 226, 227
Ravenswood, Ill 218, 219
Rochelle, Ill 219
Rochester, N. Y 154-160
Sacramento, Cal 216
Saginaw, Mich 226
Saint Louis, Mich 226
Saratoga Springs, N. Y 229, 230
Schenectady, N. Y 230
Sidney, Ohio 231
Stockyard Station, Ill 219
Sycamore, Ill 219
Taunton, Mass 223

Water-works employing the system of pumping direct into distributing mains—Continued. Page.

Titusville, Pa 232
Troy, N. Y 160-163
Union City, Ind 220, 221
Urbana, Ohio 231
Youngstown, Ohio 231, 232

Water-works employing the system of pumping to distributing reservoir:

Albany, N. Y 94-96
Allegheny, Pa 205
Attica, Ind 197
Austin, Tex 210, 211
Bellaire, Ohio 204, 205
Biddeford, Me 199
Boston, Mass 17-31
Bridgeton, N. J 201
Brooklyn, N. Y 83-90
Burlington, Vt 211
Butler, Pa 205
Cañon City, Colo 195
Cape May, N. J 201, 202
Carlisle, Pa 205, 206
Chattanooga, Tenn 210
Chester, Pa 206
Cincinnati, Ohio 101-111
Clarion, Pa 206
Cleveland, Ohio 112, 113
Cohoes, N. Y 203
Danvers, Mass 199
Danville, Va 211
De Kalb, Ill 196
East Liverpool, Ohio 205
Fort Wayne, Ind 197
Harrisburg, Pa 206
Hartford, Conn 32-34
Hudson, N. Y 203
Jersey City, N. J 202
Kennett Square, Pa 206, 207
Kingston, Mass 199, 200
Kittanning, Pa 207
La Fayette, Ind 197, 198
Lancaster, Pa 207
Lewiston, Me 199
Lincoln, Mass 200
Lockport, Ill 197
Louisville, Ky 80-82
Lowell, Mass 114-117
Lynn, Mass 200
Lyons, N. Y 203, 204
Manchester, N. H 118-122
Marysville, Cal 195
Maysville, Ky 198
Meadville, Pa 207
Mount Holly, N. J 202
Mount Joy, Pa 207, 208
Nashua, N. H 201
Nashville, Tenn 78, 79
New Albany, Ind 198
New Castle, Del 196
New Haven, Conn 97-99
Newport, Ky 198, 199
Norristown, Pa 208
Oil City, Pa 208
Oswego, N. Y 204
Oxford, Pa 208
Parker's Landing, Pa 209
Passaic, N. J 202
Paterson, N. J 202, 203
Pawtucket, R. I 163-167
Peekskill, N. Y 204
Philadelphia, Pa 125-144
Phoenixville, Pa 209
Pittsburgh, Pa 90-94
Pittston, Pa 209

Water-works employing the system of pumping to distributing reservoir—Continued. Page.
Pleasant Hill, Ky ... 199
Poughkeepsie, N. Y ... 167-171
Providence, R. I ... 70-77
Quincy, Ill ... 197
Rome, Ga ... 196
Saint Joseph, Mo ... 201
Saint Louis, Mo ... 144-152
Saint Petersburg, Pa ... 209
Salem, Mass ... 99-101
San Diego, Cal ... 195
Somerville, Mass ... 200
Summit Hill, Pa ... 209, 210
Trenton, N. J ... 203
Trinidad, Colo ... 195, 196
Waltham, Mass ... 200, 201
Westchester, Pa ... 210
West Troy, N. Y ... 204
Wilmington, Del ... 196
York, Pa ... 210

Water-works employing the system of pumping to distributing reservoir and mains:
Alton, Ill ... 246, 247
Anamosa, Iowa ... 248
Attleborough, Mass ... 249
Bethlehem, Pa ... 252
Birmingham, Ala ... 246
Bloomsburg, Pa ... 252
Bowling Green, Ky ... 249
Buffalo, N. Y ... 251, 252
Chambersburg, Pa ... 252, 253
Elizabeth, N. J ... 251
Grand Rapids, Mich ... 250
Hannibal, Mo ... 251
Jacksonville, Fla ... 246
Jacksonville, Ill ... 247
Lawrence, Mass ... 249
Lyon, Iowa ... 248
Media, Pa ... 253
Memphis, Tenn ... 253, 254
Menomonee, Wis ... 254
Morrison, Ill ... 247
New Carlisle, Ind ... 247
Ottumwa, Iowa ... 248
Peru, Ind ... 248
Plymouth, Mass ... 249, 250
Pottstown, Pa ... 253
Rome, N. Y ... 252
San Antonio, Tex ... 254
Sedalia, Mo ... 251
Springfield, Ill ... 247
West Newton, Mass ... 250
Woburn, Mass ... 250

Water-works employing the system of pumping to distributing reservoir and stand-pipe:
Allentown, Pa ... 244
Brookline, Mass ... 243
Cambridge, Mass ... 243, 244
Cleveland, Ohio ... 112, 113
Louisville, Ky ... 80-82
Milwaukee, Wis ... 244, 245
Mobile, Ala ... 243
Nashville, Tenn ... 78, 79
West Cleveland, Ohio ... 244
Zanesville, Ohio ... 244

Water-works employing the system of pumping to distributing reservoir, stand-pipe, and mains:
Catasauqua, Pa ... 260
Erie, Pa ... 260, 261
New Bedford, Mass ... 260

Water-works employing the system of pumping to stand-pipe: Page.
Augusta, Me ... 212
Belvidere, N. J ... 214
Bloomington, Ill ... 57, 58
Bristol, Pa ... 214
Charleston, S. C ... 214, 215
Chicago, Ill ... 69
Cleveland, Ohio ... 112, 113
Dallas, Tex ... 215
Detroit, Mich ... 65-69
Fall River, Mass ... 213
Lancaster, Ohio ... 214
Little Rock, Ark ... 210
Louisville, Ky ... 80-82
Millville, N. J ... 214
Nantucket, Mass ... 213, 214
Nashville, Tenn ... 78, 76
New Orleans, La ... 153, 154
Sandusky, Ohio ... 58-62
Savannah, Ga ... 212
South Bend, Ind ... 213
Terre Haute, Ind ... 213
Toledo, Ohio ... 62-65

Water-works employing the system of pumping to stand-pipe and distributing mains:
Clinton, Iowa ... 255
Houston, Tex ... 255
Wilmington, Ill ... 255

Watsonville, Cal ... 175
Waverly, N. Y ... 187
Westborough, Mass ... 181, 182
Westchester, Pa ... 210
West Cleveland, Ohio ... 244
Westerly, R. I ... 193
Westfield, Mass ... 182
West Newton, Mass ... 250
West Springfield, Mass ... 182
West Stockbridge, Mass ... 182
West Troy, N. Y ... 204

West Virginia:
Martinsburg ... 232, 233

West Winsted, Conn ... 177
Wilkesbarre, Pa ... 192, 242
Williamsport, Pa ... 192, 193
Williamstown, Mass ... 182
Wilmington, Del ... 196
Wilmington, Ill ... 255
Winchester, Mass ... 182
Winchester, Va ... 194
Windsor, Conn ... 177

Wisconsin:
Black River Falls ... 233
Fond du Lac ... 194
Kenosha ... 194
Lacrosse ... 233
Menomonee ... 254
Milwaukee ... 244, 245
Prairie du Chien ... 194

Woburn, Mass ... 250
Wolcottville, Conn ... 177, 178
Wooster, Ohio ... 187, 188
Worcester, Mass ... 182

Y.

Yonkers, N. Y ... 241
York, Pa ... 210
Youngstown, Ohio ... 231, 232
Yreka, Cal ... 175

Z.

Zanesville, Ohio ... 244

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House documents

Bd.: [351.] 1882/83, Vol. 13,17 = Congress 47, Sess. 2

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